GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION
SPONSORED PROJECT INITIATION

Date: March 17, 1980

Project Title: Marketing & Commercialization Strategy for Photovoltaic Technical Information Dissemination

Project No: A-2581

Project Director: Dr. George R. Fletcher

Energy

Sponsor: Solar Energy Research Institute (SERI); Golden, CO 80401

Agreement Period: From February 1, 1980 Until January 31, 1981

Type Agreement: Fixed Price Purchase Order No. AS-9-8338, dated 1/24/80 under D.O.E. Prime Contract No. EG-77-C-01-4042

Amount: $24,957

Reports Required: Participants List; Ind. Referral Service Report; Strategy Report; Status Bulletins; Pilot Data

Sponsor Contact Person (s):

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Defense Priority Rating: N/A

Assigned to: EEL/IED (School/Laboratory)

COPIES TO:

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- Other

28 Mar

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION SHEET

Date 9/29/81

Project Title: Marketing & Commercialization Strategy for Photovoltaic Technical Information Dissemination

Project No: A-2581

Project Director: Dr. George R. Fletcher

Sponsor: Solar Energy Research Institute (SERI); Golden, CO 80401

Effective Termination Date: 1/31/81

Clearance of Accounting Charges: _____

Grant/Contract Closeout Actions Remaining:

- [x] Final Invoice ~~and Closing Documents~~
- [ ] Final Fiscal Report
- [x] Final Report of Inventions
- [ ] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other _____

Assigned to: _____ (School/Laboratory)

COPIES TO:

Administrative Coordinator	Research Security Services	EES Public Relations (2)
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Accounting	Legal Services (OCA)	Project File
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DIRECTORY OF PHOTOVOLTAIC MANUFACTURERS, DISTRIBUTORS, AND CONSULTANTS

Prepared for

The Solar Energy Research Institute
Industrial Applications and Policy Branch
1617 Cole Boulevard
Golden, Colorado 80401

by

Technology Applications Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332
May 1981

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CHAPTER I
INTRODUCTION

In the mid 1970's, when photovlotaic (PV) systems were first identified as having the potential to supply cost-effective electrical energy for large-scale terrestrial applications, there was only a small and highly specialized photovoltaic industry. Since then, the photovoltaic industry has expanded dramatically, largely as a result of federally financed development efforts to encourage technology development and cost reduction. It has become evident that PV costs are being reduced drastically and that there will be a significant market for terrestial PV. As a result several major organizations have entered the market and either bought into or started photovoltaic companies.

There are four general categories of participants in the PV market. The first is comprised of research and development companies. These companies are supported primarily by federal contracts and perform advanced technology research and analyses. The second group is made up of manufacturers, 33 of which are identified in this report. These companies make PV cells, and in many cases they also make panels or modules; most of them manufacture either flat plate panels or concentrating modules and offer a variety of services. The third group, currently in its formative stages, distributes PV components. Several companies are actively marketing novelty items that provide a degree of consumer exposure to photovoltaics, while other distribution companies offer a variety of PV related products, including individual cells, flat plate panels, concentrating modules, voltage regulators, storage batteries, inverters, instrumentation, and complete systems. System designers and consultants make up the fourth group. Most of these firms provide photovoltaic systems design services and evaluations of applications. In addition, the large PV manufacturers provide engineering design in order to improve the market for their products.

Current participants in the photovoltaic market were identified by performing a literature search and then a telephone survey to determine what products and services were offered. The literature search was designed both to identify companies and organizations that are active in photovoltaics and to identify potential applications for PV power. To structure telephone contact with the companies, a checklist was developed. The purpose of the checklist was to insure that each point of interest was covered systematically and efficiently, and to make

sure that terms and vocabulary were used consistently. The data were tabulated, organized, and presented by several categories of reference.

The following key words were used to categorize goods and services that are available.

Photovoltaic cells
Flat plate photovoltaic panels
Concentrating (focusing) photovoltaic modules
Voltage regulators
Inverters
Load controllers
Energy storage
Instrumentation
Array structures
Complete systems
System design
System repair and maintenance
Construction management
Training
Computer simutation
Feasibility studies
Market studies
Other services

The following chapters present data gathered in these surveys.

CHAPTER II
PRODUCTS AND SERVICES

The following matrix shows the products and services that are provided by each of the firms currently active in the photovoltaic industry.

In order to present the material most concisely, letter codes are used.

M - Manufacturer
D - Distribution
R - Research
C - Consulting
X - Capability not currently exercised

COMPANY NAME	AAI Corporation	Abacus Controls, Inc.	Acurex Corp.	Aidco Maine Corp.	Aldermaston, Inc.	Ametek, Inc.	Amperex Electronic Corporation	Applied Research & Technology	Applied Solar Energy Corporation
PV CELLS					D	R			M
FLAT PV MODULES				D		R	R	D	M D
FOCUSING MODULES	M D		R M						M D
VOLTAGE REGULATOR								M D	M D
INVERTER	M D							M D	M D
LOAD CONTROLLER								M D	M D
ENERGY STORAGE					D				D
INSTRUMENTATION								M D	
ARRAY STRUCTURES	M D							M	D
COMPLETE SYSTEMS								M C	M D
SYSTEM DESIGN								X	X
SYSTEM REPAIR									X
SYSTEM CHECKOUT								X	
TRAINING									
SIMULATION									
FEASIBILITY STUDY								X	
MARKET STUDY									
OTHER SERVICES									

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
ARCO Solar, Inc.	M D	M D		M D	D	D	D	D	M D	M	X	X	X	X	X	X	X	
Arizona Public Service Company			R															
Arizona Scientific Research			M															
Arizona State University	R		R	R			R											
Arthur D. Little, Inc.		R C								R C					X			
Automatic Power, Inc.		D C	D C	M D C			D C		M D C	M D C	X	X	X	X	X	X	X	
The BDM Corporation	R C	R C	M R C							M R C	X					X		
Bechtel Corporation		R C	R C				R C	R C		R C				X	X			

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Best Energy Systems for Tomorrow					M	D												
Booze Allen & Hamilton																X		
C and D Batteries							M D											
Center for Energy Research Texas Technical University		R	R								R							
Columbia Chase Corporation (see Solar Voltaic, Inc.																		
Consumers Solar Electric Power Corporation		D								D								
Crystal Systems, Inc.	Silicon Wafers only																	X
Delatron Systems Corporation					M D		M D											
Dow Corning Corporation	R																	X

COMPANY NAME	DSET Laboratories, Inc.	Dynamote Corp.	E-Systems, Inc.	Eagle-Picher	Ecotronics, Inc.	Elgar Corp.	Elgin Solar Products	Elpower Corporation	Energy Conversion Devices
PV CELLS	R								R
FLAT PV MODULES	R				D		D		R
FOCUSING MODULES	R		M D						
VOLTAGE REGULATOR	R				M D				
INVERTER	R	M D				M D			
LOAD CONTROLLER					D				
ENERGY STORAGE	R			M D			D	M D	
INSTRUMENTATION									
ARRAY STRUCTURES	R		M D						
COMPLETE SYSTEMS	R		M D						
SYSTEM DESIGN	X	X							X
SYSTEM REPAIR									
SYSTEM CHECKOUT	X								
TRAINING	X								
SIMULATION	X								
FEASIBILITY STUDY									
MARKET STUDY									
OTHER SERVICES									

Special for Nuclear Power Industry

COMPANY NAME	Energy Harvester	ESB Incorporated	Exide Power Systems	Far West Corrosion Controls Co.	Ferranti Electric, Inc.	Free Energy Systems, Inc.	Gates Energy Products
PV CELLS							
FLAT PV MODULES				D C		D C	
FOCUSING MODULES					D		
VOLTAGE REGULATOR				M C		D C	
INVERTER						D C	
LOAD CONTROLLER				M D C			
ENERGY STORAGE	M D	M D	M D	D C		D C	M D
INSTRUMENTATION							
ARRAY STRUCTURES				M C		M D C	
COMPLETE SYSTEMS				M C		M D C	
SYSTEM DESIGN				X		X	
SYSTEM REPAIR				X		X	
SYSTEM CHECKOUT						X	
TRAINING						X	
SIMULATION						X	
FEASIBILITY STUDY				X			
MARKET STUDY							
OTHER SERVICES							

COMPANY NAME	General Electric Co.	General Motors Corporation	Globe-Union, Inc.	Gould, Inc.	Happy Days Solar Systems	Honeywell Corporation	Hydrate Battery Corp.,	Hydro-Flex Corporation
PV CELLS	M R C					R C		
FLAT PV MODULES	M R C				D			
FOCUSING MODULES	M R C					R C		
VOLTAGE REGULATOR	M D C							
INVERTER	M D C							
LOAD CONTROLLER	M D C							
ENERGY STORAGE	M D C	M	M D	M D	D		M D	
INSTRUMENTATION	M D C							M D
ARRAY STRUCTURES								
COMPLETE SYSTEMS	R C							
SYSTEM DESIGN	X					X		
SYSTEM REPAIR	X							
SYSTEM CHECKOUT	X							
TRAINING								
SIMULATION	X							
FEASIBILITY STUDY	X					X		
MARKET STUDY	X					X		
OTHER SERVICES						X		

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Independent Energy Systems, Inc.					D		D											
International Rectifier	R	R																
InterTech Solar Corporation		D	D															
IOTA Engineering, Inc.					M		M											
Keystone Battery Corp.							D											
Lockheed Missiles & Space Company, Inc.		R C	R C				R C				R C					X		
Martin-Marietta Aerospace			R C							R	X	X						
Massachusetts Institute of Technology Lincoln Laboratory	R	R		R	R	R	R	R	R	R	X		X	X	X	X	X	X
McGraw Edison				M D			M D	M D										

(Special-Low Power Lighting Only)

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
MCM Enterprises																		
Megatech Corp.		M D								C								
Microwave Associates	M																	
Mobil Tyco Solar Energy Corp.	M R	M D	M R	M R														
Monegon, Ltd.	R					R	R		R		X							
Monsanto Industrial Chemicals Co.	M R										X	X	X	X	X	X		
Motorola, Inc.	M D	M D	M D	M D	D	D	D	D	D	M D	X	X	X		X	X	X	
Mr. Sun, Inc.		D																
Mule Emergency Lighting, Inc.							M D											

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COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
NASA Lewis Research Center		R		R	R	R	R	R	C	R C	X				X	X	X	
National Bureau of Standards	R	R						R										
National Semiconductors, Ltd.	R																	
Nova Electric Manufacturing Co.							M											
Optical Coatings Laboratory, Inc. (See Applied Solar Energy Corp.)																		
Parker Products	M D																	
Owens-Illinois			M D R													X		
Photon Power Inc.	M R	M R																

051081

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Photowatt International, Inc.	M D	M D		D			D		D	M D	X	X	X				X	
Power Incorporated							M D											
Power-Sonic Corp.							M D											
Power Systems and Controls					M D													
RCA Corporation	R C	R C	R							X	X				X			
Real Gas & Electric Co.					M D													
Rockwell International	R C								M R C									
Sandia Laboratories	R	C	R	R	R	R	R	R	R	R	X	X		X	X	X	X	

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Science Applications Inc.										M								
Semicon, Inc.	M(Special) D																	
Sensor Technology, Inc.	M R	R																
SES, Incorporated	M R	M D		M			D	M			X			X	X	X	X	
Silicon Sensors, Inc.	M D R	M R									X							
Siltec Corp.	R																	
Solar Disc							M R D											
Solar Electronics		D																
Solar Electric Engineering, Inc.		D																

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COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Solar Electric Inc.										M								
Solar Electric International								D	M D	M D	X							
Solar Energy Products, Inc.		D																
Solar Energy Research Institute	R						R	R		R	X				X	X	X	
Solarex Corporation	M D R	M D R	M D R	M D	D	D	D	M D	M D	M D	X	X	X	X	X	X	X	X
Solargenics, Incorporated		M D								M D	X	X			X	X		
Solar Kinetics, Inc.			M R							M								
Solar Power Corporation	M D	M D		M D		D	D		M D	M D	X	X	X	X	X	X	X	
Solar Voltaic, Inc.	R																	

COMPANY NAME	Solar West Electric	Solec International, Inc.	Solectro-Thermal Inc.	Solenergy Corporation	Soleq Corporation	Sollos Inc.	Spectrolab	Spire Corporation
PV CELLS		M D	D C	M D		M D	M D	M D
FLAT PV MODULES	M D	M D		M D		M D		M D
FOCUSING MODULES			M D C				M D	M D
VOLTAGE REGULATOR	M D	M D	D C	M D	M D	D		
INVERTER	M D	D	D C	D	M D	D		
LOAD CONTROLLER	D	M		D		D		
ENERGY STORAGE	M D	D	D C	D	D	D	M	
INSTRUMENTATION		M	M D C	M D		D		
ARRAY STRUCTURES	M D	M D	M D C			D	X	
COMPLETE SYSTEMS	X	M D	M D C			M D	X	
SYSTEM DESIGN		X	X	X		X		
SYSTEM REPAIR	X	X	X	X		X		
SYSTEM CHECKOUT		X	X	X				
TRAINING		X		X		X		
SIMULATION		X	X					
FEASIBILITY STUDY		X	X	X		X	X	
MARKET STUDY		X		X				
OTHER SERVICES								

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Standard Solar Collectors		M D																
Strategies Unlimited																	X	
Surrette Storage Battery Co.							M D											
Talley Industries (See Ecotronics, Inc.)																		
TEAM, Inc.										C	X		X	X	X	X	X	
Technical Marketing Assoc., Inc.																	X	
Technidyne Associates										C								
Television Technology Corp.		D		D			D		D		D		X	X		X		
Texas Instruments, Inc.	M R	M R			R			R	M R		X					X		
Thermo Electron Corporation		R C																

COMPANY NAME	Tideland Signal Corporation	Topaz Electronics	Tri Solat Corporation	Trojan Batteries	Uce, Inc.	United Energy Corporation	University of Arizona	University of Nebraska	UTL Corporation	Vactec, Inc.
PV CELLS	M D						R		M D	M D
FLAT PV MODULES	M D					M D	R	R		M D
FOCUSING MODULES							R		M D	
VOLTAGE REGULATOR		M							D	
INVERTER		M							D	
LOAD CONTROLLER		M						R	D	
ENERGY STORAGE	M D	M		M D				R	D	
INSTRUMENTATION	M D							R	M D	M D
ARRAY STRUCTURES	M D							R	M D	
COMPLETE SYSTEMS	M D		D		C	M		R	M D	
SYSTEM DESIGN	X							X	X	
SYSTEM REPAIR	X								X	
SYSTEM CHECKOUT	X								X	
TRAINING	X							X	X	
SIMULATION	X							X	X	
FEASIBILITY STUDY	X								X	
MARKET STUDY									X	
OTHER SERVICES									X	

COMPANY NAME	Varian Associates	Webb Electronics	Westwind Electronics, Inc.	Westinghouse Elec. Corp.	William Lamb Co.	Willmore Electronics Company, Inc.	Windworks, Inc.	Wyle Solar Services	Zomeworks
PV CELLS	R			M R C					
FLAT PV MODULES				M R C	D			R	D
FOCUSING MODULES	R								
VOLTAGE REGULATOR		M D		M D C		M	M D		
INVERTER			M D	M D C		M	M D	R	
LOAD CONTROLLER				M D C			M D		
ENERGY STORAGE				D C			D	R	
INSTRUMENTATION	M D			M D C			M D		
ARRAY STRUCTURES				M C				R	D
COMPLETE SYSTEMS				M R C					
SYSTEM DESIGN	X			X				X	
SYSTEM REPAIR				X					
SYSTEM CHECKOUT				X					
TRAINING				X				X	
SIMULATION				X				X	
FEASIBILITY STUDY	X			X				X	
MARKET STUDY				X				X	
OTHER SERVICES									

CHAPTER III

LISTS OF MANUFACTURERS AND DISTRIBUTORS BY PRODUCT OR SERVICE

Participants in the photovoltaic market place are listed under the various categories that were defined above. These categories have been expanded and contracted as necessary to convey information more clearly.

A. PV CELL MANUFACTURERS

The following companies have the capability for manufacturing photovoltaic cells, though some of these companies are not presently manufacturing cells for sale.

Applied Solar Energy Corporation
Crystal Systems, Inc.
Microwave Associates
Monsanto Industrial Chemicals Co.
Parker Products
Photowatt International, Inc.
Sensor Technology, Inc.
Silicon Sensors, Inc.
Solar Power Corporation
Solenergy Corporation
Spectrolab
Texas Instruments, Inc.
UTL Corporation
Westinghouse Elec. Corp.
ARCO Solar, Inc.
General Electric Co.
Mobil Tyco Solar Energy Corp.
Motorola, Inc.
Photon Power Inc.
Semicon, Inc.
SES, Incorporated
Solarex Corporation
Solec International, Inc.
Sollos Inc.
Spire Corporation
Tideland Signal Corporation
Vactec, Inc.

B. PV CELL DISTRIBUTORS

The following companies distribute photovoltaic cells.

Aldermaston, Inc.
Crystal Systems, Inc.
Parker Products
Semicon, Inc.
Solarex Corporation
Solec International, Inc.
Solenergy Corporation
Spectrolab
Tideland Signal Corporation
Vactec, Inc.
ARCO Solar, Inc.
Motorola, Inc.
Photowatt International, Inc.
Silicon Sensors, Inc.
Solar Power Corporation
Solectro-Thermal Inc.
Sollos Inc.
Spire Corporation
UTL Corporation

C. FLAT PLATE PV MODULE MANUFACTURERS

The following companies manufacture flat plate photovoltaic modules.

Applied Solar Energy Corporation
General Electric Co.
Mobil Tyco Solar Energy Corp.
Owens-Illinois
Photowatt International, Inc.
Silicon Sensors, Inc.
Solargenics, Incorporated
Solar West Electric
Solenergy Corporation
Spire Corporation
Texas Instruments, Inc.
United Energy Corporation
Westinghouse Elec. Corp.
ARCO Solar, Inc.
Megatech Corp.
Motorola, Inc.
Photon Power Inc.
SES, Incorporated
Solarex Corporation
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Standard Solar Collectors
Tideland Signal Corporation
Vactec, Inc.
Zomeworks

D. FLAT PLATE PV MODULE DISTRIBUTORS

The following companies distribute flat plat photovoltaic modules.

Aidco Maine Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
Consumers Solar Electric Power Corporation
Elgin Solar Products
Free Energy Systems, Inc.
InterTech Solar Corporation
Mobil Tyco Solar Energy Corp.
Mr. Sun, Inc.
Photowatt International, Inc.
Solar Electronics
Solar Energy Products, Inc.
Solargenics, Incorporated
Solar West Electric
Solenergy Corporation
Spire Corporation
Television Technology Corp.
United Energy Corporation
William Lamb Co.
Applied Research & Technology
ARCO Solar, Inc.
Chesapeake Solar Systems
Ecotronics, Inc.
Far West Corrosion Controls Co.
Happy Days Solar Systems
Megatech Corp.
Motorola, Inc.
Owens-Illinois
SES, Incorporated
Solar Electric Engineering, Inc.
Solarex Corporation
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Standard Solar Collectors
Tideland Signal Corporation
Vactec, Inc.
Zomeworks

E. CONCENTRATING PV MODULE MANUFACTURERS

The following companies manufacture concentrating photovoltaic modules.

AAI Corporation
Applied Solar Energy Corporation
The BDM Corporation
Ecotronics, Inc.
Mobil Tyco Solar Energy Corp.
Solatex Corporation
Solectro-Thermal Inc.
Spire Corporation
Acurex Corp.
Arizona Scientific Research
E-Systems, Inc.
General Electric Co.
Motorola, Inc.
Solar Kinetics, Inc.
Spectrolab
UTL Corporation

F. CONCENTRATING PV MODULE DISTRIBUTORS

The following companies distribute concentating photovoltaic modules.

AAI Corporation
Automatic Power, Inc.
Ecotronics, Inc.
InterTech Solar Corporation
Solarex Corporation
Spectrolab
UTL Corporation
Applied Solar Energy Corporation
E-Systems, Inc.
Ferranti Electric, Inc.
Motorola, Inc.
Solectro-Thermal Inc.
Spire Corporation

G. VOLTAGE REGULATOR MANUFACTURERS AND DISTRIBUTORS

The following companies manufacture and/or distribute voltage regulators for use with photovoltaic systems.

Applied Research & Technology
ARCO Solar, Inc.
Ecotronics, Inc.
Free Energy Systems, Inc.
McGraw Edison
Motorola, Inc.
SES, Incorporated
Solar Power Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Topaz Electronics
Westinghouse Elec. Corp.
Windworks, Inc.
Applied Solar Energy Corporation
Automatic Power, Inc.
Far West Corrosion Controls Co.
General Electric Co.
Mobil Tyco Solar Energy Corp.
Photowatt International, Inc.
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Television Technology Corp.
Webb Electronics
Willmore Electronics Company, Inc.

H. INVERTER MANUFACTURERS AND DISTRIBUTORS

The following companies manufacture or distribute inverters for use with photovoltaic systems.

Abacus Controls, Inc.
Applied Solar Energy Corporation
Best Energy Systems for Tomorrow, Inc.
Dynamote Corp.
Free Energy Systems, Inc.
Independent Energy Systems, Inc.
Motorola, Inc.
Real Gas & Electric Co.
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Topaz Electronics
Westinghouse Elec. Corp.
Windworks, Inc.
Applied Research & Technology
ARCO Solar, Inc.
Delatron Systems Corporation
Elgar Corp.
General Electric Co.
IOTA Engineering, Inc.
Power Systems and Controls
Solarex Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Westwind Electronics, Inc.
Willmore Electronics Company, Inc.

I. LOAD CONTROLLER MANUFACTURERS AMD DISTRIBUTORS

The following companies manufacture or distribute load controllers for use with photovoltaic systems.

Applied Research & Technology
ARCO Solar, Inc.
Ecotronics, Inc.
General Electric Co.
Solarex Corporation
Solar West Electric
Solenergy Corporation
Topaz Electronics
Windworks, Inc.
Applied Solar Energy Corporation
Best Energy Systems for Tomorrow, Inc.
Far West Corrosion Controls Co.
Motorola, Inc.
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Westinghouse Elec. Corp.

J. ENERGY STORAGE MANUFACTURERS

The following companies manufacture energy storage systems for use with photovoltaic systems.

Braden Wire & Metal Products, Inc.
Chesapeake Solar Systems
Eagle-Picher
Energy Harvester
Exide Power Systems
General Electric Co.
Globe-Union, Inc.
Hydrate Battery Corp.,
McGraw Edison
Nova Electric Manufacturing Co.
C and D Batteries
Delatron Systems Corporation
Elpower Corporation
ESB Incorporated
Gates Energy Products
General Motors Corporation
Gould, Inc.
Keystone Battery Corp.
Mule Emergency Lighting, Inc.
Power Incorporated

J. ENERGY STORAGE MANUFACTURERS (Continued)

Power-Sonic Corp.
Solar West Electric
Surrette Storage Battery Co.
Topaz Electronics
Solar Disc
Spectrolab
Tideland Signal Corporation
Trojan Batteries

K. ENERGY STORAGE DISTRIBUTORS

The following companies distribute energy storage systems for use with photovoltaic systems.

Aldermaston, Inc.
ARCO Solar, Inc.
Braden Wire & Metal Products, Inc.
Chesapeake Solar Systems
Eagle-Picher
Elpower Corporation
ESB Incorporated
Far West Corrosion Controls Co.
Gates Energy Products
Globe-Union, Inc.
Happy Days Solar Systems
Independent Energy Systems, Inc.
McGraw Edison
Mule Emergency Lighting, Inc.
Power Incorporated
Power Systems and Controls
Solar Disc
Solar Power Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Television Technology Corp.
Trojan Batteries
Westinghouse Elec. Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
C and D Batteries
Delatron Systems Corporation
Elgin Solar Products
Energy Harvester
Exide Power Systems
Free Energy Systems, Inc.
General Electric Co.
Gould, Inc.
Hydrate Battery Corp.,
Keystone Battery Corp.
Motorola, Inc.
Photowatt International, Inc.
Power-Sonic Corp.
SES, Incorporated
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Surrette Storage Battery Co.
Tideland Signal Corporation
UTL Corporation
Windworks, Inc.

L. INSTRUMENTATION MANUFACTURERS AND DISTRIBURORS

The following companies manufacturer or distribute instrumentation for use with photovoltaic systems.

Applied Research & Technology
General Electric Co.
McGraw Edison
SES, Incorporated
Solarex Corporation
Solectro-Thermal Inc.
Sollos Inc.
UTL Corporation
Varian Associates
Windworks, Inc.
ARCO Solar, Inc.
Hydro-Flex Corporation
Motorola, Inc.
Solar Electric International
Solec International, Inc.
Solenergy Corporation
Tideland Signal Corporation
Vactec, Inc.
Westinghouse Elec. Corp.

M. ARRAY STRUCTRUES MANUFACTURERS AND DISTRIBURORS

The following companies manufacture or distribute array structures.

AAI Corporation
Applied Solar Energy Corporation
Automatic Power, Inc.
Far West Corrosion Controls Co.
Motorola, Inc.
Rockwell International
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Television Technology Corp.
Tideland Signal Corporation
Westinghouse Elec. Corp.
Applied Research & Technology
ARCO Solar, Inc.
E-Systems, Inc.
Free Energy Systems, Inc.
Photowatt International, Inc.
Solar Electric International
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Texas Instruments, Inc.
UTL Corporation
Zomeworks

N. COMPLETE SYSTEMS MANUFACTURERS AND DISTRIBURORS

The following companies are able to provide complete photovoltaic systems. These firms consist of manufacturers, distributors, and consultants.

Applied Research & Technology
ARCO Solar, Inc.
The BDM Corporation
E-Systems, Inc.
Free Energy Systems, Inc.
Motorola, Inc.
Science Applications Inc.
Solar Electric International
Solargenics, Incorporated
Solar Power Corporation
Solectro-Thermal Inc.
Tideland Signal Corporation
United Energy Corporation
Westinghouse Elec. Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
Consumers Solar Electric Power Corp.
Far West Corrosion Controls Co.
MCM Enterprises
Photowatt International, Inc.
Solar Electric Inc.
Solarex Corporation
Solar Kinetics, Inc.
Solec International, Inc.
Sollos Inc.
Tri Solar Corporation
UTL Corporation

CHAPTER IV
ALPHABETICAL LISTING

The following pages provide an alphabetical listing of the photovoltaic manufacturers, distributors, and consultants. Chapter II presents the products of each of these firms in a matrix form.

051081

AAI Corporation
P.O. Box 6767
Baltimore, Maryland 21204
(301) 666-1400

Abacus Controls, Inc.
P.O. Box 893
Somerville, New Jersey 08876
(201) 526-6010

Acurex Corp.
485 Clyde Avenue
Mt. View, CA 94042
(415) 964-3200

Aidco Maine Corp.
Orr's Island, ME 04066
(207) 833-6700

Aldermaston, Inc.
P.O. Box 32
Locust Valley, NY 11560
(516) 676-6198

Ametek, Inc.
Operation Headquarters
Station Square 2
Paoli, Pa. 19301
(215) 647-2121

Amperex Electronic Corporation
Providence Pike
Statersville Ri. 02876
(401) 762-7900

Applied Research & Technology
Utah - ARTU
1918 N. 90 W.
Orem, UT 84057
(801) 224-2594

Applied Solar Energy Corporation
15251 E. Don Dulian Rd.
City of Industry, CA 91746
(213) 968-6581

ARCO Solar, Inc.
20554 Plummer St.
Chatsworth, CA 91311
(213) 998-0667

Arizona Public Service Company
411 North Central Avenue
Phoenix, Arizona 85036
(602) 271-2194

Arizona Scientific Research
10121 Catalina Highway
Tucson, AZ 85715
(602) 749-3954

Arizona State University
Mechanical Engineering Department
Tempe, Arizona 85281
(602) 965-3857

Arthur D. Little, Inc.
25 Acorn Park
Cambridge, MA 02140
(617) 864-5770

Automatic Power, Inc.
213 Hutcheson Street
Houston, TX 77023
(713) 228-5208

The BDM Corporation
2600 Yale Boulevard, S.E.
Albuquerque, New Mexico 87106
(505) 843-7870

Bechtel Corporation
50 Beale Street
San Francisco, California 94119
(415) 768-5430

Best Energy Systems for Tomorrow, Inc.
P.O. Box 280, Rt. 1
Necedah, WI 54646
(608) 565-7200

C and D Batteries
3043 Walton Road
Plymouth Meeting, PA 19462
(215) 828-9000

Center for Energy Research
Texas Technical University
Lubbock, Texas 79409
(806) 742-3543

Columbia Chase Corporation
(see Solar Voltaic, Inc.

Consumers Solar Electric
Power Corporation
5811 Uplander Way
Culver City, Ca. 02343
(213) 670-0513

Crystal Systems, Inc.
Shetland Industrial Park
35 Congress St.
Salem, MA 01970
(617) 745-0088

Delatron Systems Corporation
553 Lively Boulevard
Elk Grove Village, IL 60007
(312) 593-2270

Dow Corning Corporation
Solar Energy
2200 West Salzburg Rd., Box 1767
Midland, MI 48640
(517) 496-4000

DSET Laboratories, Inc.
Box 1850, Black Canyon State
Phoenix, AZ 85029
(602) 465-7356

Dynamote Corp.
1130 N.W. 85th
Seattle, WA 98117
(206) 282-1000

E-Systems, Inc.
Energy Technology Center
P.O. Box 6118
Dallas, Texas 75222
(214) 272-0515

Eagle-Picher
Commercial Products Dept.
P. O. Box 130
Seneca, MO 64865
(417) 776-2258

Ecotronics, Inc.
7745 East Redfield Road
Scottsdale, AZ 85260
(602) 948-8003

Elgar Corp.
8225 Mercury Ct.
San Diego, CA 92111
(714) 565-1155
(800) 854-2213

Elgin Solar Products
P.O. Box 548
Elgin, TX 78621
(521) 285-3385

Elpower Corporation
2117 S. Anne Street
Santa Ana, CA 92704

Energy Conversion Devices
1175 W. Maple Rd.
Troy, MI 48084
(313) 280-1900

Energy Harvester
11807 Bernardo Terrace
Sand Diego, CA 92128
(714) 485-8454

ESB Incorporated
2510 North Blvd.
Raleigh, NC 27604
(919) 834-8465

Exide Power Systems
5 Penn Center Plaza
25th Floor, Phildelphia, PA 19103
(215) 265-6060

Far West Corrosion Controls Co.
17311 S. Main St.
Gardena, CA 90248
(213) 532-9524 or 770-6425

Ferranti Electric, Inc.
87 Modular Ave.,
Commack, NY 11725
(516) 543-0200

Free Energy Systems, Inc.
Holmes Industrial Park
Holmes, PA 19043
(215) 583-4780

Gates Energy Products
1050 S. Broadway
Denver, CO 80217
(303) 744-4806

General Electric Co.
Space Division
P.O. Box 13601
Philadelphia, PA 19101
(215) 962-2112

General Motors Corporation
Box 2439
Anderson, IN 46011
(317) 644-5581

Globe-Union, Inc.
Battery Div.
Dept. G.
5759 N. Green Bay Ave.
Milwaukee, WI 53201
(414) 228-1200

Gould, Inc.
Portable Battery Div.
931G Vandalia St.
St. Paul, MN 55114
(612) 645-8531

Happy Days Solar Systems
722 Gulfcrest
San Antonio, TX 78239
(512) 656-0274

Honeywell Corporation
2600 Ridgeway Parkway
Minneapolis, Minnesota 55413
(612) 378-5496

Hydrate Battery Corp.
3220 Odd Fellows Rd.
P.O. Box 10773
Lynchburg, VA 24506
(804) 846-8749

Hydro-Flex Corporation
2107 N.W. Brickyard Rd.
Topeka, KS 66618
(913) 233-7484

Independent Energy Systems, Inc.
113 East 13th
Erie, PA 16503
(814) 454-1543

International Rectifier
233 Kansas Street
El Segundo, Ca. 90245
(213) 322-3331

InterTech Solar Corporation
100 Main Street
Warrenton, Virginia 22186
(703) 347-9500

IOTA Engineering, Inc.
1735 East Ft. Lowell Road
Tucson, AZ 85719
(602) 327-5781

Keystone Battery Corp.
35 Holton St.
Winchester, MA 01890
(617) 729-8333

Lockheed Missiles
& Space Company, Inc.
1111 Lockheed Way
Sunnyvale, CA 94088
(408) 742-4321

Martin-Marietta Aerospace
12250 S. Hwy. 75, Box 179
Denver, CO 80201
(303) 973-3000

Massachusetts Institute of
Technology Lincoln Laboratory
P.O. Box 73
Lexington, Massachusetts 02173
(617) 862-5500

McGraw Edison
Edison Battery Division
210 Redstone Hill Road
Bristol, CT 06010
(203) 582-6321

MCM Enterprises
PO Box 7707
Sanford, CA 94305
(415) 493-3333

Megatech Corp.
29 Cook St.
Billerica, MA 01821
(617) 273-1900

Microwave Associates
43 South Avenue
Burlington, MA 01803
(617) 272-3000

Mobil Tyco Solar Energy Corp.
16 Hickory Drive
Waltham, MA 12154
(617) 890-0909

Monegon, Ltd.
4 Professional Drive, Suite 130
Gaithersburg, MD 20760, U.S.A.
(301) 258-7540

Monsanto Industrial Chemicals Co.
800 North Lindbergh Boulevard
St. Louis, MO 63166
(314) 694-2153

Motorola, Inc.
Solar Energy Dept.
5005 E. McDowell Rd.
P.O. Box 20924
Phoenix, AZ 85036
(602) 244-5459

Mr. Sun, Inc.
1811 Aga Drive
Alexandria, MN 56308
(612) 763-3606

Mule Emergency Lighting, Inc.
600 Park Avenue
Cranston, RI 02910
(401) 785-9250

NASA Lewis Research Center
21000 Brookpark Road
Cleveland, Ohio 44135
(216) 433-3000 ext. 6840

National Bureau of Standards
Washington, D.C. 20234
(301) 921-3625

National Semiconductors, Ltd.
331 Cornelia Street
Plattsburgh, NY 12901
(518) 561-3160

Nova Electric Manufacturing Co.
263 Hillside Avenue
Nutley, NJ 07110
(201) 661-3434

Optical Coatings Laboratory, Inc.
(See Applied Solar Energy Corp.)

Owens-Illinois
P.O. Box 1035
Toledo, Ohio 43666
(419) 247-8906

Parker Products
10 Pierce Street
Reading, MA 01867
(617) 944-8668

Photon Power Inc.
10787 Gateway West
El Paso, TX 79935
(915) 539-2861

Photowatt International, Inc.
2414 West Fourteenth St.
Tempe, Az. 85281
(602) 894-9564

Power Incorporated
12809 Eagle Ridge Drive
Burnsville, MN 55337
(612) 890-1360

Power-Sonic Corp.
P.O. Box 5242
3106 Spring Street
Redwood City, CA 94063
(415) 364-5001

Power Systems and Controls
1730 Kelly Road
Richmond, VA 23261
(804) 355-2803

RCA Corporation
David Sarnoff Research Center
P.O. Box 432
Princeton, New Jersey 08540
(609) 452-2700 ext. 3212

Real Gas & Electric Co.
P.O. Box F
Santa Rosa, CA 95402
(707) 526-3400

Rockwell International
Science Center
Thousand Oaks, California 91360
(805) 498-4545

Sandia Laboratories
Albuquerque, New Mexico 87115
(505) 264-4041

Science Applications Inc.
8400 Westpark Drive
McLean, VA 22102
(703)827-4783

Semicon, Inc.
14 North Avenue
Burlington, MA 01803
(617) 272-9015

Sensor Technology, Inc.
21012 Lassen St.
Chatsworth, CA 91311
(213) 882-4100

SES, Incorporated
Tralee Industrial Park
Newark, De. 19711
(302) 731-0990

Silicon Sensors, Inc.
Solar Systems, Div.
Highway 18
E. Dodgeville, WI 53533
(608) 935-2707

Siltec Corp.
3717 Haven Ave.
Menlo Park, CA 94025
(415) 365-8600

Solar Disc
540 Lagoon Drive
Honolulu, HI 96819
(808) 833-0001

Solar Electric Engineering, Inc.
438 W. Cypress Street
Glendale, CA 91204
(213) 246-7200

Solar Electric Inc.
4837 Del Ray Avenue
Washington, D. C. 20014
(301) 656-9614

Solar Electronics
156 Drakes Lane
Summertown, Tn. 38483
(615) 964-2222

Solar Electric International
4837 Del Ray Avenue
Washington, D.C. 20014
(301) 656-9614

Solar Energy Products, Inc.
P. O. Box 1048
Gainsville, FL 32601
(904) 377-6527

Solar Energy Research Institute
1536 Cole Boulevard
Golden, Co. 80401
(303) 231-1410

Solarex Corporation
1335 Piccard Drive
Rockville, MD 20850
(301) 948-0202

Solargenics, Incorporated
9831 Mason Ave.
Chatsworth, CA. 91311
(213) 998-0806

Solar Kinetics, Inc.
8120 Chancelor Road
Dallas, Texas 75247
(214) 630-9328

Solar Power Corporation
20 Cabot Rd.
Woburn, Ma 01801
(617) 935-4600

Solar Voltaic, Inc.
224 Forbs Rd.
Braintree, Ma. 02184
(617) 848-2810

Solar West Electric
1124 Coast Village Circle
Santa Barbara, CA 93108
(805) 969-6845

Solec International, Inc.
12533 Chadron Avenue
Hawthern, Ca. 90250
(213) 970-0065

Solectro-Thermal Inc.
1934 Lakeview Ave.
Dracut, Ma. 01826
(617) 957-0028

Solenergy Corporation
23 North Avenue
Wakefield, MA 01880
(617) 246-1855

Soleq Corporation
5969 Elston Avenue
Chicago, IL 60646
(312) 792-3811

Sollos Inc.
2231 Carmelina Avenue
Los Angeles, CA 90064
(213) 820-5181

Spectrolab
12500 Gladstone Avenue
Sylmar, CA 91342
(213) 365-4611

Spire Corporation
Patriots Park
Bedford, MA 11730
(617) 275-6000

Standard Solar Collectors
1465 Gates Avenue
Brooklyn, NY 11227

Strategies Unlimited
201 San Antonio Circle
Suite 205
Mt. View, CA 94040
(415) 941-3438

Sun Trac Corporation
540 Zenith Drive
Glenview, IL 60025
(312) 299-1080

Surrette Storage Battery Co.
P.O. Box 3027
Salem, MA 01970
(617) 745-4444

Talley Industries
(See Ecotronics, Inc.)

TEAM, Inc.
5105-G Backlick Road
Annandale, Va. 22003
(703) 642-5030

Technical Marketing Assoc., Inc.
2250 Main Street
Concord, Massachusetts 01742
(617) 369-5500

Technidyne Associates
58-06 69th Pl.
Maspeth, NY 11378
(212) 424-8448

Television Technology Corp.
Dept. G.
5970 W. 60th Ave.
Arvada, CO 80003
(303) 423-1652

Texas Instruments, Inc.
P.O. Box 5012
Dallas, Texas 75222
(214) 238-2334

Thermo Electron Corporation
101 First Avenue
Waltham, MA 02154
(617) 890-8700

Tideland Signal Corporation
4310 Directors Row
Houston, TX 77052
(713)681-6101

Topaz Electronics
5577 Kearny Villa Road
San Diego, CA 92123
(714) 565-8363

Tri Solar Corporation
6 Alfred Circle
Bedford, MA 01730
(617) 275-1200

Trojan Batteries
1395 Evans Avenue
San Francisco, CA 94124
(415) 826-2600

051081

Uce, Inc.
24 Fitch Street
East Norwalk, CT 06855
(203) 838-7509

United Energy Corporation
6666 Mapunapuna
Honolulu, HI 96819
(808) 836-1593

University of Arizona
Tucson, Arizona
(602) 884-2483

University of Nebraska
Lincoln, Nebraska 68588
(402) 472-1626

UTL Corporation
4500 West Mockingbird Lane
Dallas, Texas 75209
(214) 350-7601

Vactec, Inc.
2423 Northline Ind. Blvd.
Maryland Heights, MD 63043
(314)872-8300

Varian Associates
611 Hansen Way
Palo Alto, CA 94303
(415)493-4000

Webb Electronics
South Monaco
Denver, CO
303/399-2414

Westwind Electronics, Inc.
P.O. Box 1657
Durango, CO 81301
(303) 588-2275

Westinghouse Elec. Corp.
Advanced Energy Systems
P.O. Box 10864
Pittsburgh, PA 15236
(412)892-5600

William Lamb Co.
10615 Chandler Blvd.
North Hollywood, Ca. 91601
(213) 980-6248

Willmore Electronics Company, Inc.
P. O. Box 1329
Hillsborough, NC 27278
(919) 732-9251

Windworks, Inc.
Box 329, Route 3
Mukwonago, WI 53149
414/363-4408

Wyle Solar Services
Wyle Laboratories
7800 Governors Drive, W.
Huntsville, AL 35807
(205) 837-4411

Zomeworks
P.O. Box 721
Albuquerque, NM 87103
(505) 242-5354

GLOSSARY

ENERGY STORAGE - a bank of batteries or other mechanisms which store energy that is generated by photovoltaic array, or through inherent self-storing characteristics of the PV system. Examples of systems not requiring a battery for storage are water pumping and refrigeration systems where the water and "cold" are stored. The firms listed in this report under the catagory of Energy Storage deal with chemical storage batteries.

INVERTER - a device that changes the direct current produced by the cells or stored in batteries to alternating current for use with alternating current appliances and motors.

LOAD CONTROLLER - a device that protects the battery systems from both excessive charge and discharge.

PHOTOVOLTAIC CELLS - disks or squares of specially treated silicon or other material which, when exposed to light, generate a voltage.

PHOTOVOLTAIC MODULES - a specific grouping of photovoltaic cells which are encapsulated or sealed between metal and transparent plates. Flat plat modules - designed so that there is no focusing of sunlight on the cells. Concentrating (focusing) modules-designed to concentrate sunshine on the cells.

PHOTOVOLTAIC PANEL - another term for a flat-plate photovoltaic module.

VOLTAGE REGULATOR - a device to insure that the voltage from the photovoltaic arrays and battery systems remains within a predetermined range.

INDUSTRIAL MARKETS FOR PHOTOVOLTAIC SYSTEMS: AN ANTHOLOGY OF INFORMATION

Prepared for

The Solar Energy Research Institute
Industrial Applications and Policy Branch
1617 Cole Boulevard
Golden, Colorado 80401

by

Technology Applications Laboratory
Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia 30332
May 1981

Table of Contents

PREFACE

The Solar Energy Research Institute (SERI) has been assigned a role in technology implementation by the Department of Energy (DOE). An important part of this effort is the planning and management of a program of Technical Information Dissemination (TID) to enhance the adoption of solar technologies: solar thermal, wind, biomass, ocean thermal, and photovoltaics.

The responsibility for industrial applications of the photovoltaic portion of the TID Program has been assigned to SERI's Industrial Applications and Policy Branch. It is the goal of the program to identify potential markets for industrial applications of photovoltaic energy systems and to inform industries of the alternative of using photovoltaic energy.

The project described in this report was performed in support of the industrial photovoltaic TID efforts. It consisted of four major tasks: 1. Identification of the participants in the photovoltaic industry, 2. Development of an annotated bibliography of photovoltaic market studies, 3. Identification of market analysis data catagories, and 4. Data collection and analysis.

CHAPTER I
INTRODUCTION

This report describes the currently developing industrial market for photovoltaic (PV) systems. It addresses the supply side of the market in a directory that lists manufacturers, distributors, and consultants supplying a variety of products and services. For the demand side of the market, projections from studies of future industrial photovoltaic applications are reviewed; and a preliminary attempt is made to identify industries for which photovoltaic systems can provide power or can form components of finished products.

The purpose of the report is to supply background information useful in estimating how a future market for industrial photovoltaics applications may develop. To accomplish that purpose, data have been gathered and presented in convenient form. Primary emphasis has been placed on using existing sources; only a limited effort could be spent to develop new analysis. Background information concerns characteristics of photovoltaics suppliers: their capabilities, numbers, variety of services, locations, and addresses. It also includes "market factors" that can be used to select those industries for which photovoltaic applications appear attractive, and includes sets of industry characteristics (electrical usages, energy intensity, location, energy prices) that mark potential candidates. These bodies of information are supplemented by results of several market studies which have been abstracted and compared.

Chapter II presents the Directory of Photovoltaic Manufacturers, Distributors, and Consultants. Active participants are described by name, address, and 18 categories of goods and services currently provided. The Directory is shown in matrix form, so that a reader can obtain quick cross reference to his interest; and separate listings by product and service are also given. This information represents the most recent available data on photovoltaics suppliers.

Chapter III is a bibliography of market studies of industrial photovoltaics applications. Major studies have been abstracted, with particular attention paid to the types and quantities of systems projected for potential markets. Other entries in the bibliography provide supplementary information. In all, 44 citations were reviewed for this report.

Chapter IV describes the results of an effort to identify characteristics that favor photovoltaic power applications for industry. Data sets for industry categorized by Standard Industrial Classification Code are presented, as are data on solar insolation and electricity prices by state to provide locational criteria. Important parameters are identified qualitatively and are used to give preliminary indications of favorable circumstances for industrial photovoltaic systems.

Chapter V is a brief review of uses for photovoltaic power units as components of other products (e.g. remote communications equipment). These secondary, or manufacturing, markets for photovoltaics may provide the largest near-term opportunities in the industrial sector. Listings of 92 possible applications are given, and identification of the industry group is provided for each application.

Chapter VI summarizes information that was presented in the report and results of the study.

CHAPTER II
PHOTOVOLTAIC MANUFACTURERS, DISTRIBUTORS, AND CONSULTANTS

In the mid 1970's, when photovlotaic (PV) systems were first identified as having the potential to supply cost-effective electrical energy for large-scale terrestrial applications, there was only a small and highly specialized photovoltaic industry. Since then, the photovoltaic industry has expanded dramatically, largely as a result of federally financed development efforts to encourage technology development and cost reduction. It has become evident that PV costs are being reduced drastically and that there will be a significant market for terrestial PV. As a result several major organizations have entered the market and either bought into or started photovoltaic companies.

There are four general categories of participants in the PV market. The first is comprised of research and development companies. These companies are supported primarily by federal contracts and perform advanced technology research and analyses. The second group is made up of manufacturers, 33 of which are identified in this report. These companies make PV cells, and in many cases they also make panels or modules; most of them manufacture either flat plate panels or concentrating modules and offer a variety of services. The third group, currently in its formative stages, distributes PV components. Several companies are actively marketing novelty items that provide a degree of consumer exposure to photovoltaics, while other distribution companies offer a variety of PV related products, including individual cells, flat plate panels, concentrating modules, voltage regulators, storage batteries, inverters, instrumentation, and complete systems. System designers and consultants make up the fourth group. Most of these firms provide photovoltaic systems design services and evaluations of applications. In addition, the large PV manufacturers provide engineering design in order to improve the market for their products.

Current participants in the photovoltaic market were identified by performing a literature search and then a telephone survey to determine what products and services were offered. The literature search was designed both to identify companies and organizations that are active in photovoltaics and to identify potential applications for PV power. To structure telephone contact with the companies, a checklist was developed. The purpose of the checklist was to insure that each point of interest was covered systematically and efficiently, and to make

sure that terms and vocabulary were used consistently. The data were tabulated, organized, and presented by several categories of reference.

The following key words were used to categorize goods and services that are available.

Photovoltaic cells
Flat plate photovoltaic panels
Concentrating (focusing) photovoltaic modules
Voltage regulators
Inverters
Load controllers
Energy storage
Instrumentation
Array structures
Complete systems
System design
System repair and maintenance
Construction management
Training
Computer simutation
Feasibility studies
Market studies
Other services

The following sections present data gathered in these surveys.

I. PRODUCTS AND SERVICES

The following matrix shows the products and services that are provided by each of the firms currently active in the photovoltaic industry.

In order to present the material most concisely, letter codes are used.

M - Manufacturer
D - Distribution
R - Research
C - Consulting
X - Capability not currently exercised

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
AAI Corporation			M D						M D									
Abacus Controls, Inc.																		
Acurex Corp.			R M		D M													
Aidco Maine Corp.		D																
Aldermaston, Inc.	D						D											
Ametek, Inc.	R	R																
Amperex Electronic Corporation		R																
Applied Research & Technology		D		M D	M D	M D		M D	M	M C	X		X			X		
Applied Solar Energy Corporation	M	M D	M D	D	D	D	D		D	M D	X	X						

COMPANY NAME	ARCO Solar, Inc.	Arizona Public Service Company	Arizona Scientific Research	Arizona State University	Arthur D. Little, Inc.	Automatic Power, Inc.	The BDM Corporation	Bechtel Corporation
PV CELLS	M D			R			R C	
FLAT PV MODULES	M D				R C	D C	R C	R C
FOCUSING MODULES		R	M	R		D C	M R C	R R C
VOLTAGE REGULATOR	M D			R		M D C		
INVERTER	D							
LOAD CONTROLLER	D							
ENERGY STORAGE	D			R		D C		R C
INSTRUMENTATION	D							R C
ARRAY STRUCTURES	M D					M D C		
COMPLETE SYSTEMS	M				R C	M D C	M R C	R C
SYSTEM DESIGN	X					X	X	
SYSTEM REPAIR	X					X		
SYSTEM CHECKOUT	X					X		
TRAINING	X					X		X
SIMULATION	X				X	X		X
FEASIBILITY STUDY	X					X	X	
MARKET STUDY	X					X		
OTHER SERVICES								

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Best Energy Systems for Tomorrow					M	D												
Booze Allen & Hamilton																X		
C and D Batteries							M D											
Center for Energy Research Texas Technical University		R	R								R							
Columbia Chase Corporation (see Solar Voltaic, Inc.																		
Consumers Solar Electric Power Corporation		D								D								
Crystal Systems, Inc.	Silicon Wafers only																	X
Delatron Systems Corporation					M D		M D											
Dow Corning Corporation	R																	X

COMPANY NAME	DSET Laboratories, Inc.	Dynamote Corp.	E-Systems, Inc.	Eagle-Picher	Ecotronics, Inc.	Elgar Corp.	Elgin Solar Products	Elpower Corporation	Energy Conversion Devices
PV CELLS	R								R
FLAT PV MODULES	R				D		D		R
FOCUSING MODULES	R		M D						
VOLTAGE REGULATOR	R				M D				
INVERTER	R	M D				M D			
LOAD CONTROLLER					D				
ENERGY STORAGE	R			M D			D	M D	
INSTRUMENTATION									
ARRAY STRUCTURES	R		M D						
COMPLETE SYSTEMS	R		M D						
SYSTEM DESIGN	X		X						X
SYSTEM REPAIR									
SYSTEM CHECKOUT	X								
TRAINING	X								
SIMULATION	X								
FEASIBILITY STUDY									
MARKET STUDY									
OTHER SERVICES									

Special for Nuclear Power Industry

COMPANY NAME	Energy Harvester	ESB Incorporated	Exide Power Systems	Far West Corrosion Controls Co.	Ferranti Electric, Inc.	Free Energy Systems, Inc.	Gates Energy Products
PV CELLS							
FLAT PV MODULES				D C		D C	
FOCUSING MODULES					D		
VOLTAGE REGULATOR				M C		D C	
INVERTER						D C	
LOAD CONTROLLER				M D C			
ENERGY STORAGE	M D	M D	M D	D C		D C	M D
INSTRUMENTATION							
ARRAY STRUCTURES				M C		M D C	
COMPLETE SYSTEMS				M C		M D C	
SYSTEM DESIGN				X		X	
SYSTEM REPAIR				X		X	
SYSTEM CHECKOUT						X	
TRAINING						X	
SIMULATION						X	
FEASIBILITY STUDY				X			
MARKET STUDY							
OTHER SERVICES							

COMPANY NAME	General Electric Co.	General Motors Corporation	Globe-Union, Inc.	Gould, Inc.	Happy Days Solar Systems	Honeywell Corporation	Hydrate Battery Corp.,	Hydro-Flex Corporation
PV CELLS	M R C					R C		
FLAT PV MODULES	M R C				D			
FOCUSING MODULES	M R C					R C		
VOLTAGE REGULATOR	M D C							
INVERTER	M D C							
LOAD CONTROLLER	M D C							
ENERGY STORAGE	M D C	M	M D	M D	D		M D	
INSTRUMENTATION	M D C							M D
ARRAY STRUCTURES								
COMPLETE SYSTEMS	R C							
SYSTEM DESIGN	X					X		
SYSTEM REPAIR	X							
SYSTEM CHECKOUT	X							
TRAINING								
SIMULATION	X							
FEASIBILITY STUDY	X					X		
MARKET STUDY	X			-		X		
OTHER SERVICES						X		

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Independent Energy Systems, Inc.					D		D											
International Rectifier	R	R																
Inter Tech Solar Corporation		D	D															
IOTA Engineering, Inc.					M	(Special-Low Power Lighting Only)												
Keystone Battery Corp.							M D											
Lockheed Missiles & Space Company, Inc.		R C	R C				R C				R C					X		
Martin-Marietta Aerospace			R C							R	X	X						
Massachusetts Institute of Technology Lincoln Laboratory	R	R		R	R	R	R	R	R	R	X		X	X	X	X	X	X
McGraw Edison				M D			M D	M D										

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COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
MCM Enterprises										C								
Megatech Corp.		M D																
Microwave Associates	M																	
Mobil Tyco Solar Energy Corp.	M R	M D	M R	M R						X	X	X	X	X	X	X		
Monegon, Ltd.	R					R	R		R		X		X	X	X			
Monsanto Industrial Chemicals Co.	M R																	
Motorola, Inc.	M D	M D	M D	M D	D	D	D	D	D	M D	X	X	X		X	X	X	
Mr. Sun, Inc.		D																
Mule Emergency Lighting, Inc.							M D											

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
NASA Lewis Research Center		R		R	R	R	R	R	C	R C	X				X	X	X	
National Bureau of Standards	R	R						R										
National Semiconductors, Ltd.	R																	
Nova Electric Manufacturing Co.							M											
Optical Coatings Laboratory, Inc. (See Applied Solar Energy Corp.)																		
Parker Products	M D																	
Owens-Illinois			M D R													X		
Photon Power Inc.	M R	M R																

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COMPANY NAME	Photowatt International, Inc.	Power Incorporated	Power-Sonic Corp.	Power Systems and Controls	RCA Corporation	Real Gas & Electric Co.	Rockwell International	Sandia Laboratories
PV CELLS	M D				R C		R C	R C
FLAT PV MODULES	M D				R C			C
FOCUSING MODULES					R			R
VOLTAGE REGULATOR	D							R
INVERTER				M D		M D		R
LOAD CONTROLLER								R
ENERGY STORAGE	D	M D	M D					R
INSTRUMENTATION								R
ARRAY STRUCTURES	D						M R C	R
COMPLETE SYSTEMS	M D				X			R
SYSTEM DESIGN	X				X			X
SYSTEM REPAIR	X							X
SYSTEM CHECKOUT	X							
TRAINING								X
SIMULATION					X			X
FEASIBILITY STUDY								X
MARKET STUDY	X							X
OTHER SERVICES								

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Science Applications Inc.										M								
Semicon, Inc.	M(Special) D																	
Sensor Technology, Inc.	M R	R																
SES, Incorporated	M R	M D		M			D	M			X			X	X	X	X	
Silicon Sensors, Inc.	M D R	M R									X							
Siltec Corp.	R																	
Solar Disc							M R D											
Solar Electronics		D																
Solar Electric Engineering, Inc.		D																

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COMPANY NAME	Solar Electric Inc.	Solar Electric International	Solar Energy Products, Inc.	Solar Energy Research Institute	Solarex Corporation	Solargenics, Incorporated	Solar Kinetics, Inc.	Solar Power Corporation	Solar Voltaic, Inc.
PV CELLS				R	M D R			M D	R
FLAT PV MODULES			D		M D R	M D		M D	
FOCUSING MODULES					M D R		M R		
VOLTAGE REGULATOR					M D			M D	
INVERTER					D				
LOAD CONTROLLER					D			D	
ENERGY STORAGE				R	D			D	
INSTRUMENTATION		D		R	M D				
ARRAY STRUCTURES		M D			M D			M D	
COMPLETE SYSTEMS	M	M D		R	M D	M D	M	M D	
SYSTEM DESIGN		X		X	X	X		X	
SYSTEM REPAIR					X	X		X	
SYSTEM CHECKOUT					X			X	
TRAINING					X			X	
SIMULATION				X	X	X		X	
FEASIBILITY STUDY				X	X	X		X	
MARKET STUDY				X	X			X	
OTHER SERVICES					X				

COMPANY NAME	Solar West Electric	Solec International, Inc.	Solectro-Thermal Inc.	Solenergy Corporation	Soleq Corporation	Sollos Inc.	Spectrolab	Spire Corporation
PV CELLS		M D	D C	M D		M D	M D	M D
FLAT PV MODULES	M D	M D		M D		M D		M D
FOCUSING MODULES			M D C				M D	M D
VOLTAGE REGULATOR	M D	M D	D C	M D	M D	D		
INVERTER	M D	D	D C	D	M D	D		
LOAD CONTROLLER	D	M		D		D		
ENERGY STORAGE	M D	D	D C	D	D	D	M	
INSTRUMENTATION		M	M D C	M D		D		
ARRAY STRUCTURES	M D	M D	M D C			D	X	
COMPLETE SYSTEMS	X	M D	M D C			M D	X	
SYSTEM DESIGN		X	X	X		X		
SYSTEM REPAIR	X	X	X	X		X		
SYSTEM CHECKOUT		X	X	X				
TRAINING		X		X		X		
SIMULATION		X	X					
FEASIBILITY STUDY		X	X	X		X	X	
MARKET STUDY		X		X				
OTHER SERVICES								

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Standard Solar Collectors		M D																
Strategies Unlimited																	X	
Surrette Storage Battery Co.							M D											
Talley Industries (See Ecotronics, Inc.)																		
TEAM, Inc.										C	X		X	X	X	X	X	
Technical Marketing Assoc., Inc.																	X	
Technidyne Associates										C								
Television Technology Corp.		D		D			D		D		D		X	X		X		
Texas Instruments, Inc.	M R	M R			R			R	M R		X					X		
Thermo Electron Corporation		R C																

COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Tideland Signal Corporation	M D	M D			M	M	M D	M D	M D	M D	X	X	X	X	X	X		
Topaz Electronics				M	M	M	M											
Tri Solat Corporation										D								
Trojan Batteries							M D											
Uce, Inc.										C								
United Energy Corporation		M D								M								
University of Arizona	R	R	R															
University of Nebraska		R					R	R	R	R	X		X	X	X			
UTL Corporation	M D		M D	D	D	D	D	M D	M D	M D	X	X	X	X	X	X	X	X
Vactec, Inc.	M D	M D						M D										

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COMPANY NAME	PV CELLS	FLAT PV MODULES	FOCUSING MODULES	VOLTAGE REGULATOR	INVERTER	LOAD CONTROLLER	ENERGY STORAGE	INSTRUMENTATION	ARRAY STRUCTURES	COMPLETE SYSTEMS	SYSTEM DESIGN	SYSTEM REPAIR	SYSTEM CHECKOUT	TRAINING	SIMULATION	FEASIBILITY STUDY	MARKET STUDY	OTHER SERVICES
Varian Associates	R		R					M D			X					X		
Webb Electronics				M D														
Westwind Electronics, Inc.					M D													
Westinghouse Elec. Corp.	M R C	M R C		M D C	M D C	M D C	D C	M D C	M C	M R C	X	X	X	X	X	X	X	
William Lamb Co.		D																
Willmore Electronics Company, Inc.				M	M													
Windworks, Inc.				M D	M D	M D	D	M D										
Wyle Solar Services		R			R		R		R		X			X	X	X	X	
Zomeworks		D							D									

II. LISTS OF MANUFACTURERS AND DISTRIBUTORS BY PRODUCT OR SERVICE

Participants in the photovoltaic market place are listed under the various categories that were defined above. These categories have been expanded and contracted as necessary to convey information more clearly.

A. PV CELL MANUFACTURERS

The following companies have the capability for manufacturing photovoltaic cells, though some of these companies are not presently manufacturing cells for sale.

Applied Solar Energy Corporation
Crystal Systems, Inc.
Microwave Associates
Monsanto Industrial Chemicals Co.
Parker Products
Photowatt International, Inc.
Sensor Technology, Inc.
Silicon Sensors, Inc.
Solar Power Corporation
Solenergy Corporation
Spectrolab
Texas Instruments, Inc.
UTL Corporation
Westinghouse Elec. Corp.
ARCO Solar, Inc.
General Electric Co.
Mobil Tyco Solar Energy Corp.
Motoroia, Inc.
Photon Power Inc.
Semicon, Inc.
SES, Incorporated
Solarex Corporation
Solec International, Inc.
Sollos Inc.
Spire Corporation
Tideland Signal Corporation
Vactec, Inc.

B. PV CELL DISTRIBUTORS

The following companies distribute photovoltaic cells.

Aldermaston, Inc.
Crystal Systems, Inc.
Parker Products
Semicon, Inc.
Solarex Corporation
Solec International, Inc.
Solenergy Corporation
Spectrolab
Tideland Signal Corporation
Vactec, Inc.
ARCO Solar, Inc.
Motorola, Inc.
Photowatt International, Inc.
Silicon Sensors, Inc.
Solar Power Corporation
Solectro-Thermal Inc.
Sollos Inc.
Spire Corporation
UTL Corporation

C. FLAT PLATE PV MODULE MANUFACTURERS

The following companies manufacture flat plate photovoltaic modules.

Applied Solar Energy Corporation
General Electric Co.
Mobil Tyco Solar Energy Corp.
Owens-Illinois
Photowatt International, Inc.
Silicon Sensors, Inc.
Solargenics, Incorporated
Solar West Electric
Solenergy Corporation
Spire Corporation
Texas Instruments, Inc.
United Energy Corporation
Westinghouse Elec. Corp.
ARCO Solar, Inc.
Megatech Corp.
Motorola, Inc.
Photon Power Inc.
SES, Incorporated
Solarex Corporation
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Standard Solar Collectors
Tideland Signal Corporation
Vactec, Inc.

D. FLAT PLATE PV MODULE DISTRIBUTORS

The following companies distribute flat plat photovoltaic modules.

Aidco Maine Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
Consumers Solar Electric Power Corporation
Elgin Solar Products
Free Energy Systems, Inc.
InterTech Solar Corporation
Mobil Tyco Solar Energy Corp.
Mr. Sun, Inc.
Photowatt International, Inc.
Solar Electronics
Solar Energy Products, Inc.
Solargenics, Incorporated
Solar West Electric
Solenergy Corporation
Spire Corporation
Television Technology Corp.
United Energy Corporation
William Lamb Co.
Applied Research & Technology
ARCO Solar, Inc.
Chesapeake Solar Systems
Ecotronics, Inc.
Far West Corrosion Controls Co.
Happy Days Solar Systems
Megatech Corp.
Motorola, Inc.
Owens-Illinois
SES, Incorporated
Solar Electric Engineering, Inc.
Solarex Corporation
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Standard Solar Collectors
Tideland Signal Corporation
Vactec, Inc.
Zomeworks

E. CONCENTRATING PV MODULE MANUFACTURERS

The following companies manufacture concentrating photovoltaic modules.

AAI Corporation
Applied Solar Energy Corporation
The BDM Corporation
Ecotronics, Inc.
Mobil Tyco Solar Energy Corp.
Solatex Corporation
Solectro-Thermal Inc.
Spire Corporation
Acurex Corp.
Arizona Scientific Research
E-Systems, Inc.
General Electric Co.
Motorola, Inc.
Solar Kinetics, Inc.
Spectrolab
UTL Corporation

F. CONCENTRATING PV MODULE DISTRIBUTORS

The following companies distribute concentating photovoltaic modules.

AAI Corporation
Automatic Power, Inc.
Ecotronics, Inc.
InterTech Solar Corporation
Solarex Corporation
Spectrolab
UTL Corporation
Applied Solar Energy Corporation
E-Systems, Inc.
Ferranti Electric, Inc.
Motorola, Inc.
Solectro-Thermal Inc.
Spire Corporation

G. VOLTAGE REGULATOR MANUFACTURERS AND DISTRIBUTORS

The following companies manufacture and/or distribute voltage regulators for use with photovoltaic systems.

Applied Research & Technology
ARCO Solar, Inc.
Ecotronics, Inc.
Free Energy Systems, Inc.
McGraw Edison
Motorola, Inc.
SES, Incorporated
Solar Power Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Topaz Electronics
Westinghouse Elec. Corp.
Windworks, Inc.
Applied Solar Energy Corporation
Automatic Power, Inc.
Far West Corrosion Controls Co.
General Electric Co.
Mobil Tyco Solar Energy Corp.
Photowatt International, Inc.
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Television Technology Corp.
Webb Electronics
Willmore Electronics Company, Inc.

H. INVERTER MANUFACTURERS AND DISTRIBUTORS

The following companies manufacture or distribute inverters for use with photovoltaic systems.

Abacus Controls, Inc.
Applied Solar Energy Corporation
Best Energy Systems for Tomorrow, Inc.
Dynamote Corp.
Free Energy Systems, Inc.
Independent Energy Systems, Inc.
Motorola, Inc.
Real Gas & Electric Co.
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Topaz Electronics
Westinghouse Elec. Corp.
Windworks, Inc.
Applied Research & Technology
ARCO Solar, Inc.
Delatron Systems Corporation
Elgar Corp.
General Electric Co.
IOTA Engineering, Inc.
Power Systems and Controls
Solarex Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Westwind Electronics, Inc.
Willmore Electronics Company, Inc.

I. LOAD CONTROLLER MANUFACTURERS AND DISTRIBUTORS

The following companies manufacture or distribute load controllers for use with photovoltaic systems.

Applied Research & Technology
ARCO Solar, Inc.
Ecotronics, Inc.
General Electric Co.
Solarex Corporation
Solar West Electric
Solenergy Corporation
Topaz Electronics
Windworks, Inc.
Applied Solar Energy Corporation
Best Energy Systems for Tomorrow, Inc.
Far West Corrosion Controls Co.
Motorola, Inc.
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Westinghouse Elec. Corp.

J. ENERGY STORAGE MANUFACTURERS

The following companies manufacture energy storage systems for use with photovoltaic systems.

Braden Wire & Metal Products, Inc.
Chesapeake Solar Systems
Eagle-Picher
Energy Harvester
Exide Power Systems
General Electric Co.
Globe-Union, Inc.
Hydrate Battery Corp.,
McGraw Edison
Nova Electric Manufacturing Co.
C and D Batteries
Delatron Systems Corporation
Elpower Corporation
ESB Incorporated
Gates Energy Products
General Motors Corporation
Gould, Inc.
Keystone Battery Corp.
Mule Emergency Lighting, Inc.
Power Incorporated

J. ENERGY STORAGE MANUFACTURERS (Continued)

Power-Sonic Corp.
Solar West Electric
Surrette Storage Battery Co.
Topaz Electronics
Solar Disc
Spectrolab
Tideland Signal Corporation
Trojan Batteries

K. ENERGY STORAGE DISTRIBUTORS

The following companies distribute energy storage systems for use with photovoltaic systems.

Aldermaston, Inc.
ARCO Solar, Inc.
Braden Wire & Metal Products, Inc.
Chesapeake Solar Systems
Eagle-Picher
Elpower Corporation
ESB Incorporated
Far West Corrosion Controls Co.
Gates Energy Products
Globe-Union, Inc.
Happy Days Solar Systems
Independent Energy Systems, Inc.
McGraw Edison
Mule Emergency Lighting, Inc.
Power Incorporated
Power Systems and Controls
Solar Disc
Solar Power Corporation
Solec International, Inc.
Solenergy Corporation
Sollos Inc.
Television Technology Corp.
Trojan Batteries
Westinghouse Elec. Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
C and D Batteries
Delatron Systems Corporation
Elgin Solar Products
Energy Harvester
Exide Power Systems
Free Energy Systems, Inc.
General Electric Co.
Gould, Inc.
Hydrate Battery Corp.,
Keystone Battery Corp.
Motorola, Inc.
Photowatt International, Inc.
Power-Sonic Corp.
SES, Incorporated
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Soleq Corporation
Surrette Storage Battery Co.
Tideland Signal Corporation
UTL Corporation
Windworks, Inc.

L. INSTRUMENTATION MANUFACTURERS AND DISTRIBURORS

The following companies manufacturer or distribute instrumentation for use with photovoltaic systems.

Applied Research & Technology
General Electric Co.
McGraw Edison
SES, Incorporated
Solarex Corporation
Solectro-Thermal Inc.
Sollos Inc.
UTL Corporation
Varian Associates
Windworks, Inc.
ARCO Solar, Inc.
Hydro-Flex Corporation
Motorola, Inc.
Solar Electric International
Solec International, Inc.
Solenergy Corporation
Tideland Signal Corporation
Vactec, Inc.
Westinghouse Elec. Corp.

M. ARRAY STRUCTRUES MANUFACTURERS AND DISTRIBURORS

The following companies manufacture or distribute array structures.

AAI Corporation
Applied Solar Energy Corporation
Automatic Power, Inc.
Far West Corrosion Controls Co.
Motorola, Inc.
Rockwell International
Solarex Corporation
Solar West Electric
Solectro-Thermal Inc.
Television Technology Corp.
Tideland Signal Corporation
Westinghouse Elec. Corp.
Applied Research & Technology
ARCO Solar, Inc.
E-Systems, Inc.
Free Energy Systems, Inc.
Photowatt International, Inc.
Solar Electric International
Solar Power Corporation
Solec International, Inc.
Sollos Inc.
Texas Instruments, Inc.
UTL Corporation
Zomeworks

N. COMPLETE SYSTEMS MANUFACTURERS AND DISTRIBURORS

The following companies are able to provide complete photovoltaic systems. These firms consist of manufacturers, distributors, and consultants.

Applied Research & Technology
ARCO Solar, Inc.
The BDM Corporation
E-Systems, Inc.
Free Energy Systems, Inc.
Motorola, Inc.
Science Applications Inc.
Solar Electric International
Solargenics, Incorporated
Solar Power Corporation
Solectro-Thermal Inc.
Tideland Signal Corporation
United Energy Corporation
Westinghouse Elec. Corp.
Applied Solar Energy Corporation
Automatic Power, Inc.
Consumers Solar Electric Power Corp.
Far West Corrosion Controls Co.
MCM Enterprises
Photowatt International, Inc.
Solar Electric Inc.
Solarex Corporation
Solar Kinetics, Inc.
Solec International, Inc.
Sollos Inc.
Tri Solar Corporation
UTL Corporation

III. ALPHABETICAL LISTING

The following pages provide an alphabetical listing of the photovoltaic manufacturers, distributors, and consultants including addresses and telephone numbers.

051081

AAI Corporation
P.O. Box 6767
Baltimore, Maryland 21204
(301) 666-1400

Abacus Controls, Inc.
P.O. Box 893
Somerville, New Jersey 08876
(201) 526-6010

Acurex Corp.
485 Clyde Avenue
Mt. View, CA 94042
(415) 964-3200

Aidco Maine Corp.
Orr's Island, ME 04066
(207) 833-6700

Aldermaston, Inc.
P.O. Box 32
Locust Valley, NY 11560
(516) 676-6198

Ametek, Inc.
Operation Headquarters
Station Square 2
Paoli, Pa. 19301
(215) 647-2121

Amperex Electronic Corporation
Providence Pike
Statersville Ri. 02876
(401) 762-7900

Applied Research & Technology
Utah - ARTU
1918 N. 90 W.
Orem, UT 84057
(801) 224-2594

Applied Solar Energy Corporation
15251 E. Don Dulian Rd.
City of Industry, CA 91746
(213) 968-6581

ARCO Solar, Inc.
20554 Plummer St.
Chatsworth, CA 91311
(213) 998-0667

Arizona Public Service Company
411 North Central Avenue
Phoenix, Arizona 85036
(602) 271-2194

Arizona Scientific Research
10121 Catalina Highway
Tucson, AZ 85715
(602) 749-3954

Arizona State University
Mechanical Engineering Department
Tempe, Arizona 85281
(602) 965-3857

Arthur D. Little, Inc.
25 Acorn Park
Cambridge, MA 02140
(617) 864-5770

Automatic Power, Inc.
213 Hutcheson Street
Houston, TX 77023
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Best Energy Systems for Tomorrow, Inc.
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C and D Batteries
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Plymouth Meeting, PA 19462
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Center for Energy Research
Texas Technical University
Lubbock, Texas 79409
(806) 742-3543

Columbia Chase Corporation
(see Solar Voltaic, Inc.

Consumers Solar Electric
Power Corporation
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Crystal Systems, Inc.
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DSET Laboratories, Inc.
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Energy Harvester
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Far West Corrosion Controls Co.
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Free Energy Systems, Inc.
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Standard Solar Collectors
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Brooklyn, NY 11227

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South Monaco
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Advanced Energy Systems
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CHAPTER III
PHOTOVOLTAIC MARKET STUDIES

A literature search was conducted to identify previously performed market studies dealing with industrial photovoltaic power applications. The literature search included a survey of computerized data bases at SERI and Oak Ridge National Laboratory and the hard copy collection of the Georgia Institute of Technology library. Relevant articles and reports were obtained and studied to extract information on industrial photovoltaic markets.

Market identification and analysis began in a serious fashion in 1973 with a study by Heliotek. To date, there have been six comprehensive studies to identify the market for terrestrial applications of photovoltaic powered systems. Their major purpose was to define the type and level of federal support for the development of the photovoltaic technology.

In addition to the six comprehensive market identification and analysis studies, there have been several studies that support and expand information available about terrestrial photovoltaic markets. Some of these utilize the basic information from the market identification and analysis studies to compare results and to develop certain areas that were either weak or outside the scope of the initial studies. The Photovoltaic Venture Analysis, the Solar Energy Research and Development: Program Balance, the Export Potential for Photovoltaic Systems, and the Overview of Photovoltaic Market Research are examples of studies that used the market identification and analysis studies as a basis. Expanding on the scope were such studies as Application and System Design Study for Cost - Effective Solar Photovoltaic Systems at Federal Installations, and Assessment of Technology Transfer Potential of Federal Photovoltaic Power System Applications to Commercial Markets. All of these studies provide information that is revalent to the comprehensive area of terrestrial photovoltaic markets and are therefore grouped together.

A second category of market-related studies which addressed markets for specific applications of terrestrial photovoltaic systems was identified. For example, NASA Lewis Research Center conducted market studies as part of their Tests and Applications Projects to complement specific demonstration projects. If the preliminary study indicated that a significant market might exist, a more

thorough market study was commissioned. These studies addressed only specific market areas.

A third category of studies provided information to support the market-related studies. These studies include engineering feasibility, economic feasibility and conceptual design studies. Even though these studies were not intended to examine the photovoltaic markets per se, they contain much valuable information directly supportive of market and application estimates. They are grouped separately and identified accordingly.

Generally, market studies have identified near term markets consisting of small isolated applications. These applications include battery chargers for boats, barrier flashers, telephone power for remote areas, TV receivers in remote areas, and solar water pumps. Larger applications such as industrial systems fall in the same category as utility systems, usually relegated to the mid-and long-term future when costs for photovoltaic cells and storage systems are expected to have been greatly reduced. These features will be seen in the market estimates in the following report abstracts.

Photovoltaic market studies and market-related studies have been abstracted and divided into three groups. The first group of studies are comprehensive analyses of near-term markets. The second group is comprised of less comprehensive efforts directed at one of a few specific applications. The third group is a set of studies that add detail ancillary to the major market analyses.

I. COMPREHENSIVE MARKET INFORMATION

The following citations and annotations are for studies relevant to the comprehensive area of near-term market for terrestrial photovoltaic power systems. Included are the market identification and analysis studies and other studies that provide comprehensive information relevant to the markets for terrestrial photovoltaic systems.

Study of Terrestrial Applications of Solar Cell Powered Systems

Heliotek, Division of Fextron, Inc.
NASA Lewis Research Center
AUTHOR: Ravin, Jerry W.
Sept. 1973, NAS CR-134512

Abstract: This study was initiated to search out, list and evaluate terrestrial applications of solar cells and design systems for those applications that show the most promise for becoming practical and accepted by users within the next five years.

The study includes the definition, categorization, evaluation and screening of the most attractive potential terrestrial applications for solar cells. Analysis of markets with high growth rates and large volumes is most likely to reveal candidates that would accept new product and system concepts. Potential markets are initially grouped and categorized in a general sense and are weighted in priority by their business volume, present and future. From a categorized list including marine, transportation, security, communication, meteorological and others, 66 potential solar cell applications have been catalogued.

A methodology was formulated to include the criteria for evaluation and screening. The evaluation process covers all parts and components of the complete system required for each application and gives consideration to all factors, such as engineering, economic, production, marketing and other factors that may have an influence on the acceptance of the system by potential users. From the list of potential solar cell applications, ten applications were selected for further study. A brief description of each of the ten recommended applications is included, along with its function, requirements, advantages, disadvantages and an estimate of the performance of the overall system. Preliminary dimensional and weight specification and anticipated production volume and unit cost of the systems are also included. The study culminated in a detailed engineering design of systems to fulfill the two most attractive applications.

Market Conclusions: This was the first major attempt to define the terrestrial applications for photovoltaic cells. The objective of this study was to identify applications that could be developed by 1978 and long range markets. Fourteen market segments were identified for initial investigation. Fifty applications were identified as having potential for fruition within five years. These applications were subjected to engineering, economic, market, production, and opinion analysis to select 10 applications with the highest probability of success. No estimates were made about the market size or system costs for cost effectiveness. at the time of the study, PV modules cost ~ $50/W. The following is a list of the applications studied in detail.

(1) Solar panels to maintain charge on boat batteries

(2) Barrier flashers, warning lights for traffic control

(3) Power supply for CCTV surveillance system

(4) Power for telephone communication in remote areas

(5) Power for TV receivers in remote areas for reception of educational programs via satellite

(6) Standard low power module - portable - forestry communication system

(7) Solid state anemometer power supply

(8) Power supply for instrumentation used to monitor noise pollution

(9) Power supply for remote perimeter protection devices

(10) Solar water pump system

Mission Analysis of Photovoltaic Solar Energy Conversion. Volume I. Executive Summary

Aerospace Corp., El Segundo, CA. Energy and Transportation Div.

*Department of Energy.

AUTHOR: Leonard, S. L.; Rattin, E. J.; Siegel, B.

GRAI7907, Mar. 77, 128p., Contract: EY-76-C-03-1101

Abstract: An investigation of terrestrial applications for the photovoltaic conversion of solar energy is summarized. The specific objectives of the study were: (a) to survey and evaluate near-term (1976—1985) civilian photovoltaic applications in the United States; (b) to evaluate the most promising major missions for the mid-term period (1986—2000) and to determine the conditions under which photovoltaic technology can compete in those applications at array prices consistent with ERDA goals; (c) to address critical external issues and identify the sensitivity of photovoltaic system technical requirements to such factors; and (d) to quantify the societal costs of alternative energy sources and identify equalizing incentives. The study was divided into six separate but interrelated tasks: Task 1, Analysis of Near-Term Applications; Task 2, Analysis of Major Mid-Term Missions; Task 3, Review and Updating of the ERDA Technology Implementation Plan; Task 4, Critical External Issues; Task 5, The Impact of Incentives; and Task 6, The Societal Costs of Conventional Power Generation. The emphasis of the study was on the first two of these tasks, the other four serving to provide supplementary information.

Market Conclusions: This study was a systematic effort to identify and define the civilian near-term markets (1976-1985) for photovoltaic systems. The definition of promising applications was based on both technical and economic factors. Secondary data sources were used to define these markets. The most significant aspect of this study was the attempt to estimate the market size. The methodology employed was to categorize applications that had been previously identified and expand on those applications by using applications tree. The applications tree was developed by systematically identifying related applications to increase the number of possible applications. Since many applications may not be realistic markets, only the most promising applications were selected for further analysis, based on the array breakeven cost. The year of initial market penetration was estimated. The size and cost of a representative application was estimated based on comparisons with conventional power systems. Then the market potential was estimated based on interviews, expert judgements, and trend projections.

Near-term market size

Float chargers for general aviation aircraft	20 KW peak
Applications	10-20 KW peak
Battery chargers for consumer products	15 KW
Intrusion detection	1300 KW
Earthquake observation	9 KW
Environmental observation	34 KW
National boarder intrusion sensors	100 KW
Industrial security sensors	1200 KW
Fire lookout towers	230 KW
Highway call boxes	10 KW
Emergency location transmitters	15 KW
Emergency position indicating radio beacons	20 KW
Radio control	100 KW
Common carrier repeater	600 KW
Private microwave repeater	800 KW
UHF/VHF repeater	550 KW
Railroad crossing signals	1400 KW
Highway signs	9000 KW
Marine navigation	400 KW
Other railroad applications	1000 KW
Drip Irrigation	22000 KW
Recreational	1700 KW
Industrial corrosion protection	8300 KW
Bridge decking corrosion protection	4000 KW
Highway rest areas	500 KW

In addition, the following markets were identified but no forecasts were made.

Fire protection sensors
Approach sensors
Status sensing instrumentation for water utilities
Location sensors
Community call boxes
Air traffic beacons and radio and lighted landing aids
Railroad black signals and controls
Highway traffic signals and controls
Fixed and mobile radio stations
Rural telephone systems
Radio and TV receivers (remote location)
Utility meter reading systems
Billboards and lighted communicators
Offshore platforms
Obstruction lights
Drinking water well pumps
Miscellaneous farm applications
Water well casing corrosion protection
Water distribution piping corrosion protection
Indian reservation needs
Grade crossing illumination
Campground power
Highway illumination
Highway maintenance depots
Boat battery float charging
Water purification
Construction site applications

(ERA citation 04:002840)
SAN-1101/PA8-1/1

Mission Analysis of Photovoltaic Solar Energy Conversion. Volume II. Survey of Near-Term (1976—1985) Civilian Applications in the United States

Aerospace Corp., El Segundo, Calif. Energy and Transportation Div. *Department of Energy.

AUTHOR: Rattin, E. J.

GRAI7823, Mar. 77, 184p., Contract: EY-76-C-03-1101-008

Abstract: The purpose of this market study was to identify and evaluate potential terrestrial civilian photovoltaic applications in the U.S. which were most likely to contribute significantly to the growth of near-term (to 1985) markets. A survey was conducted which led to the identification of many potential applications for photovoltaic power. These applications were subjected to a screening process which selected about 50 application groupings with considerable promise as near-term markets for photovoltaic arrays. For 21 of these 50 promising application groups, it was possible to make quantitative market estimates that totaled 13 MW/peak in projected annual array sales in 1985. The markets associated with the remaining 29 groups could not be quantitatively evaluated because of lack of an adequate existing data base and because the primary research required in order to provide such a data base was not feasible within the resources available in the study. If the average size of the markets associated with the unquantified groups, however, is comparable to the average for the quantified cases, then the total non-military U.S. market for arrays may well exceed 25 MW/peak/year in 1985. Foreign and U.S. military markets should add significantly to this total. In fact, the consensus of the photovoltaic industry representatives who were contacted is that the total foreign market over the near term may be several times as large as the domestic one.

Mission Analysis of Photovoltaic Solar Energy Conversion. Volume III. Major Missions for the Mid-Term (1986--2000)

Aerospace Corp., El Segundo, Calif. Energy and Transportation Div.

*Department of Energy.

AUTHOR: Leonard, S. L.; Rattin, E. J.; Siegel, B.

GRAI7822, Mar. 77, 216p., Contract: EY-76-C-03-1101-008

Abstract: The results of analyses of potentially attractive applications for photovoltaic solar energy systems in the 1985--2000 time period are presented. Primary emphasis has been given to studies of central station power plant applications, largely because it is believed that photovoltaic systems will have to achieve an appreciable penetration of that market if they are to make a significant (1--2%) contribution to the nation's energy supply by the year 2000. Earlier analyses of such applications have been extended in the current study in order to develop information on such issues as: the desirability of concentrating systems; the feasibility and economics of using the waste heat available from high concentration water-cooled systems; the effect of geographic location and fossil fuel prices and price escalation rates on allowable array prices; the attractiveness of electrical storage; and the effect of relaxing utility reliability requirements. In order to conduct these analyses, a number of supporting activities were completed. (ERA citation 03:039670)
SAN-1101/PA8-1/3

DOD Photovoltaic Energy Conversion Systems Market Inventory and Analysis.

BDM Corp., Vienna, Va.

*Federal Energy Administration, Washington, D.C.

Task Force on Solar Energy Commercialization.

AUTHOR: Terry, Robert M.; Carter, Clarence P.; Israel, Judy; Merrill, Orin H.; Semmans, Michael G.

GRAI7802, GRAI8004, Jun. 77, 219p. See also Volume 2, PB-273 970. Also available in set of 3 reports PC E11, PB-273 968-SET.

Abstract: This report provides realistic estimates of the potential DOD market for photovoltaics for a range of scenarios examined. An assessment has been made of potential actions which the DOD can take to accelerate industry and market development of photovoltaics. The principal focus of the study is on delineating near term DOD markets. Analyses indicate that a large DOD and private sector market for photovoltaic energy systems should develop as unit array costs decline from the current price of $15.50 per peak watt (Wp) to $2/Wp or less. Such a decline would be expected to occur if mass production techniques replaced the current handcrafted production processes. These markets could sustain rapid industry development into the early 1980's. At this point, major new intermediate term markets must be developed to support continued industry growth. Eventually prices may decline to the point where photovoltaic energy systems are cost effective relative to commercial electric power. The advantages to DOD offered by photovoltaics are discussed. In addition to potential cost and fuel savings, photovoltaic energy systems would provide the DOD a highly reliable, silent power source allowing virtually unattended operation in most areas of the world. Near term benefits to the DOD include cost and logistics savings at remote sites, in portable equipment and offshore applications. The national benefits from accelerated commercialization of photovoltaics are considered. Over the longer term, photovoltaic energy systems will offer the nation a cost competitive source of commercial electric power or provide a user-owned dispersed source of power, thus reducing dependence on foreign energy sources. Other national benefits include the development of exports to underdeveloped countries where photovoltaic systems could be utilized for rural electrification and irrigation pumping.
Volume II contains the appendices to support Volume I.
Contents: Statement of work; Near term application of P/V energy systems--detailed data and results; long term application of P/V energy systems--detailed data and results; combined energy systems; market survey of technology transfer potential of DOD photovoltaic applications; technology transfer potentials for non-DOD applications.

Market Conclusions: This is a very thorough study of the DOD potential market for photovoltaic power systems. In evaluating cost effectiveness, a "national value" approach to life cycle costing was used. This implies values for cost of money, and discount rate that are significantly lower than those used for private industry.

There are many applications that are cost effective for photovoltaic arrays that cost $15/W while a market of up to 100 MW per year for pV arrays that cost $2/W. These applications are mostly small isolated systems that replace primary

batteries. There is a much larger demand 100 MW/year when the array cost drops to $1-2/W.

The U.S. military is unique in its mission and organization as compared to industry. There are many application for relatively small, isolated power sources. The military also has an accounting system that allows them to accurately determine where and how many times each application occurs. Therefore, the approach used in this study was to survey to identify applications and then to use the logistical rewards to determine the demand associated with each application. This data were used to project the demand for photovoltaic power based on a power system design developed for each application and the projection of PV array costs.

This report also gives a good breakdown of the types of applications, the size of the market, many of the specific locations and an estimate of which ones are cost effective for various array costs. In the near-term (1985) the cost effective applications can be categorized as remote sites, portable equipment, and offshore uses. (ERA citation 04:051245)
DOE/TIC-10451, PB-273 969/6ST

DOD Photovoltaic Energy Conversion Systems Market Inventory and Analysis.

Summary Volume BDM Corp., Vienna, Va.

*Federal Energy Administration, Washington, D.C.

Task Force on Solar Energy Commercialization.

AUTHOR: Terry, Robert M.; Carter, Clarence P.; Israel, Judy; Merrill, Orin H.;

Semmans, Michael G. GRAI7802, Jun. 77, 40p.,

Monitor: FEA/G-77/362, See also Volume 2, PB-273 970.

Abstract: This report provides estimates of the potential Department of Defense market for photovoltaic energy systems, and the potential role of the DOD in promoting industry and market development. The focus of the study is on delineating near term markets. It is hoped that rapid development of these markets will provide sufficient sales volume to promote industry automation and drive down the unit cost of photovoltaic energy systems to the point where large scale DOD and civilian markets will develop. PB-273 971/2ST

DOD Photovoltaic Energy Conversion Systems Market Inventory and Analysis. Volume II

BDM Corp., Vienna, Va.
*Federal Energy Administration, Washington, D.C. Task Force on Solar Energy Commercialization.
AUTHOR: Terry, Robert M.; Carter, Clarence P.; Israel, Judy; Merrill, Orin H.; Semmans, Michael G.
GRAI7802, Jun. 77, 285p., Monitor: FEA/G-77/283
See also PB-273 971, and Volume I, PB-273 969.

Abstract: Contents: Statement of work; Near term application of P/V energy systems--detailed data and results; Long term application of P/V energy systems--detailed data and results; Combined energy systems; Market survey of technology transfer potential of DOD photovoltaic applications; Technology transfer potentials for non-DOD applications.

PB-273 970/4ST

Solar Energy Research and Development: Program Balance. Annex, Volume I

SRI International, Menlo Park, CA.

*Department of Energy.

GRAI7907, Feb. 78, 156p., Contract: EA-77-C-01-2693.

Abstract: An evaluation of federal research, development, and demonstration options on solar energy is presented. This assessment treats seven groups of solar energy technologies: solar heating and cooling of buildings, agricultural and industrial process heat, biomass, photovoltaics, thermal power, wind, and ocean thermal energy conversion. The evaluation methodology is presented in detail.

The discussion of the photovoltaic technology gives a brief history and describes the current state of development at the time the paper was written ($17/W). Even at that price several applications represent cost effective markets. The development program and the cost goals are defined as well as projected component costs for the period 1975 to 2020.

Market Conclusions: At $17/W there are several applications that are cost effective specifically battery chargers for mountaintop weather stations (and other isolated battery charging), radio repeater stations, forest lookout towers, warning lights for offshore structure and channel buoys, and cathodic corrosion inhibitors for pipelines. In addition it was concluded that the international marketplace is expected to be the driving force for the commercial development of photovoltaic cells in the near future. The example of powering educational television in India, Malaysia, and the Ivory coast was cited as a cost effective application since diesel power provides electrical energy at $6 to $8/KWH in isolated locations of developing countries.
(ERA citation 04:002717)
HCP/M2693-01

Solar Energy Research and Development: Program Balance. Annex, Volume II

SRI International, Menlo Park, CA.

*Department of Energy.

Abstract: Each of the seven solar energy technologies that have been assessed in the study are treated: photovoltaic devices, solar thermal power systems, wind energy systems, solar heating and cooling systems, agricultural and industrial heat processes, biomass conversion technologies, and ocean thermal energy conversion systems. A brief technical overview of storage for solar electric technologies is presented and some principles concerning how different levels of success on electrical storage can affect the commercial viability of solar electric options are discussed. A description is given of the solar penetration model that was developed and applied as an analytical tool in the study. This computer model has served the primary purpose of evaluating the competiveness of the solar energy systems in the markets in which they are expected to compete relative to that of the alternative energy sources. This is done under a variety of energy supply, demand, and price conditions. The seven sections treating the solar energy technologies contain discussions on each of six subject areas: description of the technology; economic projections; the potential contribution of the technology in different marketplaces; environmental considerations; international potential; and the present and possible future emphases within the R and D program. The priority item for each of the technology sections has been the documentation of the economic projections. The emphasis is on the technology sections and is designed to support Annex Volume I.
(ERA citation 04:002718)
HCP/M2693-02

SERI Photovoltaic Venture Analysis: Long Term Demand Estimation

Massachusetts Inst. of Tech., Cambridge. Energy Lab.

*Solar Energy Research Inst., Golden, CO.

AUTHOR: Tabors, Richard D.; Finger, Susan; Burns, Allen; Carpenter, Paul; Dinwoodie, Thomas

GRAI7925, Jul. 78, 64p., Rept No: MIT/EL-78/032

Abstract: This report presents the results of a sectoral demand analysis for photovoltaic power systems used in the residential sector (single family homes), the service, commercial, and institutional sector (schools), and in the central power sector. The results described are the output of a set of three normative modeling activities carried out by the MIT Energy Laboratory. They are based on the assumption that the actors, i.e., the utilities, schools, and homeowners, will switch to photovoltaic power systems when they are cost-effective relative to the competition, that is, centralized power generation using conventional fuels. In each case the assumption is made that the market for photovoltaic power systems will be a new market, not a retrofit market. As a result the annual (total for utilities) sales potential at a given price is estimated for each sector assuming a specific level of new installations in that sector, i.e., new single-family homes, new schools, and additions to utility stocks. As such, the results presented are maxima for a given application. While the methodology presented does not allow for any early acceptors, it does assume that once economic all new homeowners, school-builders, and utilities will buy to a fixed level.

Market Conclusions: The bulk of the demand in the market sectors addressed will not occur in the near term and much of the demand will only be realized on a long term basis. The demand estimates are difficult to put in realistic perspective because of two assumptions: first, the retrofit market was ignored, and second, it was assumed that photovoltaic systems would be used on all new structure once the price is low enough to make the technology cost effective. PB-299 388/9ST

Photovoltaic Venture Analysis. Final Report. Volume I. Executive Summary

Solar Energy Research Inst., Golden, CO.

*Department of Energy.

AUTHOR: Costello, D.; Posner, D.; Schiffel, D.; Doane, J.; Bishop, C., GRAI7917,

Jul. 78, 225p., Contract: EG-77-C-01-4042

Abstract: The objective of the study, government programs under investigation, and a brief review of the approach are presented. Potential markets for photovoltaic systems relevant to the study are described. The response of the photovoltaic supply industry is then considered. A model which integrates the supply and demand characteristics of photovoltaics over time was developed. This model also calculates the economic benefits associated with various government subsidy programs. Results are derived under alternative possible supply, demand, and macroeconomic conditions. A probabilistic analysis of the costs and benefits of a $380 million federal photovoltaic procurement initiative, as well as certain alternative strategies, is summarized. Conclusions and recommendations based on the analysis are presented.

Market Conclusions: The objective of this study was to investigate the costs, benefits and risks of an eight-year $380 million program (FY 1979-1986) in which the federal government subsidizes the difference between the price charged by photovoltaic producers and the maximum price the consumer will pay. This program referred to as "procurement initiative," is designed to reduce photovoltaic system prices to $1 to .50/W by stimulating a large demand at relatively high prices. The methodology was to define a "Base case" strategy of continued federal R & D but no "procurement initiation." A computer model was developed based on the "Base case" and this was used to estimate the impacts of altering specific parameters on the market development. Sales and price estimates were developed and modeled for 14 separate markets from 1978 to 2006. The data for this model is drawn heavily from market studies and a market demand workshop held as part of this study. The impacts of near-term and intermediate-term markets are modeled. One of the key features of the model is market penetration V.S. module cost relationships for each market sector. For the near term markets, communications and corrosion protection are the only major market considered. The basic conclusion was that the "procurement" initiative was not an effective mechanism to achieve the required photovoltaic system reductions. DOE would do better investing its money in research to make a "price breakthrough" possible than creating a market prematurely. A detailed description of the market and systems information as well as the results of the market demand workshop are included in the appendices.
(ERA citation 04:025845)
SERI/TR-52-040(V.I)

Photovoltaic Venture Analysis. Final Report. Volume II. Appendices Solar Energy Research Inst., Golden, CO.

*Department of Energy.

AUTHOR: Costello, D.; Posner, D.; Schiffel, D.; Doane, J.; Bishop, C., GRAI7917, Jul. 78, 294p., Contract: EG-77-C-01-4042

Abstract: A description of the integrating model for photovoltaic venture analysis is given; input assumptions for the model are described; and the integrating model program listing is given. The integrating model is an explicit representation of the interactions between photovoltaic markets and supply under alternative sets of assumptions. It provides a consistent way of assembling and integrating the various assumptions, data, and information that have been obtained on photovoltaic systems supply and demand factors. Secondly, it provides a mechanism for understanding the implications of all the interacting assumptions. By representing the assumptions in a common, explicit framework, much more complex interactions can be considered than are possible intuitively. The integrating model therefore provides a way of examining the relative importance of different assumptions, parameters, and inputs through sensitivity analysis. Also, detailed results of model sensitivity analysis and detailed market and systems information are presented.
SERI/TR-52-040(V.2)

Photovoltaic Venture Analysis. Final Report. Volume III. Appendices

Solar Energy Research Inst., Golden, CO.

*Department of Energy.

AUTHOR: Costello, D.; Posner, D.; Schiffel, D.; Doane, J.; Bishop, C., GRAI7917,

Jul. 78, 402p., Contract: EG-77-C-01-4042

Abstract: This appendix contains a brief summary of a detailed description of alternative future energy scenarios which provide an overall backdrop for the photovoltaic venture analysis. Also included is a summary of a photovoltaic market/demand workshop, a summary of a photovoltaic supply workshop which used cross-impact analysis, and a report on photovoltaic array and system prices in 1982 and 1986. The results of a sectorial demand analysis for photovoltaic power systems used in the residential sector (single family homes), the service, commercial, and institutional sector (schools), and in the central power sector are presented. An analysis of photovoltaics in the electric utility market is given, and a report on the industrialization of photovoltaic systems is included. A DOE information memorandum regarding "A Strategy for a Multi-Year Procurement Initiative on Photovoltaics (ACTS No. ET-002)" is also included.
(ERA citation 04:025847)
SERI/TR-52-040(V.3)

Application and System Design Study for Cost-Effective Solar Photovoltaic Systems at Federal Installations. Preliminary Report, Planning Research Corp., McLean, VA. *Department of Energy.

GRA17917, Nov. 78, 70p., Contract: EG-77-C-01-2522

Abstract: The Department of Energy Act of 1978--Civilian Applications (Public Law 95-238, Section 208) charged the Department of Energy with working cooperatively with other Federal agencies to assess the potential for the use of photovoltaic energy systems in the Federal community. An initial identification of the potential sites and uses of solar photovoltaic systems at Federal agencies has been made, and although only preliminary, indicates that there is a substantial market for life-cycle cost-effective photovoltaic applications within the Federal community for both immediate use, and into the intermediate and projected future. Analysis of the results of the preliminary survey for the cost-effective applications for photovoltaic power systems within the Federal community indicates that there are approximately $10 to $20 million (total installed costs) of photovoltaic applications that can be installed immediately after completion of system and structural designs. This appears, however, to be only a small percentage of the universe of applications since the time allowed to meet Congressional reporting deadlines was insufficient for a more comprehensive survey. Assessment of sites will continue over the next few months and the final report in February 1979 will contain additional applications as well as the detailed plan for implementation of the photovoltaic systems procured.

Market Conclusions: Although this is only a preliminary report, individual agencies surveyed Federal installations to determine the size of equipment, to determine the life cycle cost effectiveness. Their reports indicated that even though the cost of (PV) energy are high, they are cost effective on a lifetime basis when compared to conventional alternatives. Applications were identified on an agency by agency basis and analyzed for cost effectiveness. Ten federal agencies submitted 196 applications for the use of photovoltaic systems. These applications represented 1,603 site specific locations of which 1,535 were determined to be cost effective in the near term with array costs of $11.25/W peak. This report contains specific lists of applications and the number of sites for each application.
(ERA citation 04:022008)
HCP/CS-0306

Photovoltaic Power Systems Market Identification and Analysis.

BDM Corp., McLean, VA.

*Department of Energy.

GRAI7919, Nov. 78, 276p., Contract: EG-77-C-01-2533

Abstract: The following subjects are studied: present worldwide market for photovoltaic power systems, potential applications of photovoltaic P/V power systems, an approach for generating product/market scenarios, product/market scenarios for P/V powered street and highway lighting, attic fans, power/market scenario for school power systems, product/market scenarios for P/V powered irrigation pumping systems, and product/market scenario for Indian village applications.

Market Conclusions: The objective of this study was to identify and analyze near-term and intermediate term applications of photovoltaic power systems on a worldwide basis. The methodology was to brainstorm to identify applications and then to screen the application for technical and economic feasibility. The results was a list of 30 major applications and a total of over 1000 applications. These applications were then analyzed to estimate market size. This study was very thorough ahd systematic. The enclosed figure gives an overview of the number of applications by major sector. The report analyzes each application to determine the cost of the photovoltaic system that would break even for each of the major application sectors. Results of the sector analyses were used to project market demand for photovoltaic power systems. In addition to the analytical results this report discusses the factors that will influence the market and defines market scenarios in five applications. (ERA citation 04:032904)
HCP/M2533-01/2

Export Potential for Photovoltaic Systems

Battelle Pacific Northwest Labs., Richland, WA.

*Department of Energy.

GRAI7924 Apr. 79, 207p., Contract: EY-76-C-06-1830

Abstract: The purpose of this study was to provide a preliminary assessment of the export potential of U.S. photovoltaic products and systems. The need for such a study was identified by Congress in the Department of Energy Act of 1978--Civilian Applications. (Public Law 95-238, Section 208. The study deals with the following issues regarding the potential export of photovoltaic products. (1) What is the nature of the technology. (2) What are the characteristics of the market. (3) How large is the potential market. (4) How large a share of the market can the U.S. expect based upon past performance. (5) What is the U.S. position relative to the potential foreign competition. (6) What determines potential success in exporting. (7) What policy issues will influence market size and market share. The approach to market assessment in this study uses growth trends for a selected number of applications presently in use, combined with a diffusion or growth model based upon historical examples of technological innovations. The findings from this method predict that the international market for photovoltaic power systems will grow from the present one-half megaWatt of annual production to an annual demand of 100 to 1400 megaWatts by the year 2000. This quantitative assessment is intended to be conservative; it therefore assumes only incremental technological improvements and that cost reductions do not accelerate faster than DOE price goals. It does not include any assumed effects of specific government policies to increase the size of the market or U.S. market share.

Market Conclusions: This study extrapolates the results of domestic market studies to the export market. No special attempt was made to identify new applications for photovoltaic energy but rather to determine which previously identified markets had significant export potential. The international market for photovoltaic power systems will grow to an annual demand of 100 to 1400 MW by the year 2000 based on the DOE price goals. International markets have already emerged for photovoltaic systems in a variety of remote and specialty applications, which include:

- o consumer products
- o anti-corrosion equipment
- o microwave repeaters
- o remote telemetry
- o navigational and warning equipment.

The major potential foreign markets for photovoltaic systems are water pumping and village power systems. These applications are still in their infancy but have become of considerable interest to development organizations, developing countries and potential foreign competitors.

Key findings from this foreign market forecast for existing applications are: By 1986 the foreign market will be almost four times the size of the U.S. domestic market. Present sales volumes are about equal.

The projected growth of the foreign market by 1986 is largely attributed to the potential water pumping and village power applications in developing countries. A mid-range estimate is that present applications would contribute about 14 megaWatts of sales, while water pumping and village power would contribute 39 megaWatts.
Continued reductions in the cost of basic assemblies of photovoltaic cells will increase the importance of total system sales. Presently, cell modules represent from 50 to 80 percent of total system price. This will fall to 20 to 30 percent by 1986.

Although reduced photovoltaic module costs are essential to market growth, the major barrier to rapid foreign market pentration is lack of potential user familiarity with and confidence in photovoltaic power systems. Cost reductions in the early 1980s will not necessarily stimulate rapid increases in sales volume without an adequate demonstration and promotion program.
A comparison of the research, development and institutional supports and incentives for U.S., European and Japanese firms suggests that the U.S. presently leads in technology, but lags by a matter of years behind European firms in demonstrating and promoting photovoltaic applications in developing countries. There are 18 such demonstration projects sponsored by European governments, while the U.S. has only two.

European and Japanese government export support and incentives are demonstrably more effective than those of the U.S.
American photovoltaic firms have not developed a marketing infrastructure abroad, particularly in less developed countries. This places them at an initial disadvantage with large Japanese and European firms who already have such an infrastructure in place.

The findings suggest that U.S.-European competition will be strong during the initial phases of market growth, with the U.S. leading in cell technology, while European firms will have a better position in "turn-key" applications systems and in marketing strength. Later Japanese entry into the market will increase competition along the same lines. (ERA citation 04:046835)
DOE/CS-0078

Photovoltaic Power Systems Market Identification and Analysis. Final Report, January 1977--February 1978

InterTechnology/Solar Corp., Warrenton, VA.

*Department of Energy.

GRAI7924, May 79, 550p. Contract: EG-77-C-01-4022

Abstract: This report summarizes the work done by InterTechnology/Solar Corporation, its consultants, Mobil Tyco Solar Energy Corporation and the University of Delaware Institute for Energy Conversion, and its consultants, during the marketing analysis of near and intermediate term photovoltaic power applications. To obtain estimates of the domestic and foreign market potential for photovoltaically powered devices two approaches were used. First, the study was identifying then screening all possible photovoltaic power supply applications. This approach encompassed the first two tasks of the study: (1) a survey of the current uses of photovoltaic systems, both domestic and international, and a projection of the usage of those systems into the future; and (2) a new idea generation task which attempted to come up with new ways of using photovoltaic power. Second, the study required in-depth analysis of key near-term and intermediate-term photovoltaic applications identified during the first phase to obtain reasonable estimates of photovoltaic market potential. This process encompassed the third and fourth tasks of the analysis: (3) refinement of ideas generated in Task 2 so that certain products/applications could be identified, the product defined and a market survey carried out; and (4) development of a detailed product scenario which forecasts sales, barriers to market acceptance, and technical innovationsrequired for proper introduction of the products. The work performed and findings of each task are presented.

Market Conclusions: This report provides a systematic approach to the identification of present uses for photovoltaic power systems and the documentation of concept generation sessions to identify new applications. This report defined the market size by major market segment for the year 1976 and the market size is projected for each of these market segments. The market segments considered were: communications, corrosion protection, navigation aids, recreation, other consumer, miscellaneous, commercial satellite, USCG, DOD, NASA, and DOE. The thrust of the approach of this study was that photovoltaics will not sell alone. Therefore, the sales must be linked with an end product.

Some sophisticated customers will design their own product but significant market penetration will only be associated with the simultaneous availability of photovoltaics and products to use them with. Therefore, a significant portion of the report was devoted to identifying new products and the development of product description sheets on 32 photovoltaic products. This report also identifies some of the market factors that are important to each market for the selection of a vendor, such as: specifications, form of packaging, market coverage, service, application assistance, reputation, record in field, and price. Estimates of the annual market were made for each of the major market sectors under consideration. The market in 1977 was estimated to be 390 KW, in 1980 to be 4566 KW and 25966 in 1982. (ERA citation 04:046072)
HCP/T4022-01

Assessment of the Technology Transfer Potential of Federal Photovoltaic Power System Applications to Commercial Markets. Final Report

Science Applications, Inc., McLean, VA.

*Department of Energy. AUTHOR: Jaras, T. F. GRAI8015, Jun. 79, 153p. Contract: EM-78-C-04-4261

Abstract: An assessment of the market potential of photovoltaic power supplies is presented. Markets analyzed include the water pumping market, marine navigational aids, cathodic protection, remote general power sources, telecommunications, air navigational aids, mobile generator market, instrumentation, and utility connected applications.

Market Conclusions: This report uses the experience gained from FPUP and extrapolated the data to the civilian market to estimate the market size of 17 application sectors. Each of these markets is described and the potential annual market size estimated. The market sectors in order of importance are:

1. Indian residences .7KW
2. Water pumping
3. Air navaids & communications (.3-50 KW)
4. Telecommunications (1.5KW)
5. Remote general power (3KW)
6. Marine Navaids, Lighthouses (.3KW)
7. Marine Navaids, other (.3KW)
8. Remote sensors, security (.5-3KW)
9. Cathodic protection, pipeline
10. Air navaids, instrumentation (.3KW)
11. Air navaids, marking & warning (.3KW)
12. Military mobile generator (1.5KW)
13. Telecommunications (1.5KW)
14. Marine navaids, lights (.5KW)
15. Portable generator systems (.2-2KW)
16. Cathodic protection, water tanks, bridges, etc.
17. Instrumentation (.04-.05KW)

(ERA citation 05:011590) ALO-4261-T8

Overview of Photovoltaic Market Research

Solar Energy Res. Inst. Golden, Col.

AUTHOR: Costello, Dennis; Posner, David

Sol. Cells v. 1, n. 1, Nov. 1979, pp. 37-53

Available information on current and potential markets for photovoltaics is compared and contrasted. The major markets considered are communications, cathodic protection, international agricultural pumping and remote general power, and U.S. residential applications. Each of these markets is described by market size, competing power sources and system prices required for photovoltaics to compete. It is concluded that some growth in sales to communications and cathodic protection markets can be expected in the near term. International markets can be expected in the near term. International markets for agricultural pumping and general power systems show the greatest potential for sales in the early to mid 1980s. Major energy displacing markets in the U.S., particularly in the residential sector, can be a large and profitable long term market for photovoltaics.

Market Conclusions: This brief paper draws from data in several market studies and compares the data and draws conclusions about the near-term, intermediate-term and long-term markets. Photovoltaics are cost effective today for a variety of communications and corrosion protection applications both in the U.S. and in other countries. Sales by U.S. photovoltaic companies have grown from approximately 400 kWp year^{-1} in 1976 to nearly 1 MWp in 1978. Sales in 1979 may exceed 1 MWp. Approximately half of these current sales are estimated to be in non-U.S. markets. Although the majority of commercial sales are being made in near-term markets, sales in intermediate markets such as water pumping and remote general power are also being made. Many intermediate market sales are for government-supported demonstration projects.

Opportunities for growth in near-term markets exist but they are limited. The upper limit on the estimates of the potential size of these markets is approximately 25 MWp year^{-1}. Sales are likely to remain below this potential. Intermediate potential markets in the U.S. are primarily in street and highway lighting and DOD applications. Statistical estimates of the potential size of these markets are lage (nearly 400 MWp year^{-1}). Whether or not photovoltaic systems will meet the technical and institutional requirements of these markets is not presently known. Economic analyses of lighting systems also suggest that photovoltaic system prices may need to be reduced to as little as \$2 Wp^{-1} or less for photovoltaics to be economically competitive. These prices are approaching the system prices at which photovoltaics will compete in long-term U.S. residential electricity markets.

Intermediate markets outside the U.S. for pumping and remote general power systems could support industry growth in the early and mid 1980s. The combined potential size of these pumping and remote power markets may exceed 300 MWp year^{-1}. Available market data also suggest that the potential of these same markets may be as low as 25 MWp year^{-1}. Country and application specific market studies need to be concluded before more accurate estimates of the potential of these and other possible international markets can be made.

Studies of long-term markets confirm that a large and profitable market for photovoltaics exists if major reductions in the costs and prices of photovoltaic systems can be made. The promise of penetrating major U.S. energy markets will continue to motivate photovoltaic research and development and private investments in the technology. In the meantime, a wide variety of markets may develop which will encourage companies to sell photovoltaic systems today and increase sales with modest reductions in photovoltaic system prices. These markets offer a chance for the photovoltaic industry to implement research and development advances and to acquire further experience with various production and marketing techniques.

II. APPLICATION RELATED MARKET STUDIES

The following citations and annotations are for market studies that address either specific applications or a limited number of applications for near-term markets for photovoltaic power.

Photovoltaic Refrigeration Application: Assessment of the Near-Term Market

National Aeronautics and Space Administration, Cleveland, Ohio. Lewis Research Center.

*Department of Energy.

AUTHOR: Rosenblum, L.; Bifano, W. J.; Poley, W. A.; Scudder, L. R.

GRAI7814, Dec. 77, 18p., Rept No: NASA-TM-73876, Contract: EX-76A-29-1022

Abstract: A preliminary assessment of the near-term market for photovoltaic refrigeration applications (both foreign and domestic) is presented. This assessment was performed as part of the Tests and Applications Project being conducted by NASA-LeRC as part of the Department of Energy's (DOE) National Photovoltaic Program. One of the objectives of that Program is to stimulate the demand for photovoltaic power systems so that appropriate markets will be developed in concert with the increasing photovoltaic production capacity also being supported by DOE. The refrigeration application represents a possible market for photovoltaics; hence a brief survey of potential applications was conducted. Both refrigerators and refrigeration systems are considered in the assessment although the primary emphasis is on refrigerators of 9 cu ft or less. Three user sectors are examined: (1) government, (2) commercial/institutional, and (3) general public. The two areas identified with greatest market potential are refrigerators for (1) recreational vehicles in the United States and (2) for preservation of perishable medicines and food stuffs in remote areas, both foreign and domestic.

Market Conclusions: This was a short report and was intended as a preliminary assessment. It identified several potential markets for photovoltaic powered refrigeration, most of which were in isolated locations. Examples include fire towers and medical refrigeration in isolated locations. Applications such as for recreational vehicles will not be competative until the cost of photovoltaic power is $1-2/w. (ERA citation 03:023356)
DOE/NASA/1022-77/23

Photovoltaic Remote Instrument Applications: Assessment of the Near-Term Market National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AUTHOR: Rosenblum, L.; Scudder, L. R.; Poley, W. A.; Bifano, W. J. STAR16, 10 Dec. 77, 19p., Rept No: NASA-TM-73881; DOE/NASA/1022-77/24, Contract: E(49-26)-1022

Abstract: A preliminary assessment of the near term market for photovoltaic remote instrument applications is presented. Among the potential users, two market sectors are considered: government and private. However, the majority of the remote systems studied are operated by or for the federal, state, or local governments. Environmental monitoring and surveillance remote instrument systems are discussed. Based on information obtained in this preliminary market survey, a domestic, civilian market of at least 1.3 MW sub pk is forecast for remote instrument systems. This estimate is exclusive of several potentially large scale markets for remote instruments which are identified but for which no hard data is available.

Market Conclusions: This study was performed as a complement to specific applications that were developed and tested as part of the Tests and Applications Project. This study used previous market identification studies as a basis and then concentrated on the remote instrument applications. Manufacturers and users were contacted and the types and number of applications for each type were identified. The report includes a list of contacts as well as a list of potential users and a partial list of system applications. The study disclosed that there was already a market penetration of photovoltaic power supplies of 1-1.5 KW in 1976 with estimates that the annual market will be 30KW/year by 1986 in the environmental monitoring area alone. In general it was found that the market area was difficult to assess with a significant degree of accuracy because there are a large number of diverse applications, each of which have specific requirements and none of the applications represent a large market.
N78-19710/0ST

Photovoltaic Highway Applications: Assessment of the Near-Term Market.

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AUTHOR: Rosenblum, L.; Scudder, L. R.; Bifano, W. J.; Poley, W. A.,

STAR1608, Dec. 77, 12p., Rept No: NASA-TM-73863; DOE/NASA/1022-77/22,

Contract: E(49-26)-1022.

Abstract: A preliminary assessment of the near-term market for photovoltaic highway applications is presented. Among the potential users, two market sectors are considered: government and commercial. Within these sectors two possible applications, signs and motorist aids, are discussed. Based on judgmental imformation, obtained by a brief survey of representatives of the two user sectors, the government sector appears more amenable to the introduction of photovoltaic power sources for highway applications in the near-term. However, considerable interest and potential opportunities were also found to exist in the commercial sector. Further studies to quantify the market for highway applications appear warranted.

Market conclusions: This was a preliminary study to justify a more complete market study. There were six government applications identified. (1) information signs, (2) hazard warning signs, (3) control signs, (4) call boxes, (5) rest stops, and (6) information centers. Three commercial applications were identified: (1) billboards, (2) on-site signs, and (3) railroad crossing signs and signals. No estimates of market size were made.

N78-17935/5ST

Photovoltaic Village Power Application: Assessment of the Near-Term Market

National Aeronautics and Space Administration, Cleveland, Ohio. Lewis Research Center.

*Department of Energy.

AUTHOR: Rosenblum, L.; Bifano, W. J.; Poley, W. A.; Scudder, L. R.

GRAI7820, Jan. 78, 30p., Rept No: NASA-TM-73893, Contract: EY-76-C-05-1022

Abstract: A preliminary assessment of the near-term market for photovoltaic village power applications is presented. One of the objectives of the Department of Energy's (DOE) National Photovoltaic Program is to stimulate the demand for photovoltaic power systems so that appropriate markets will be developed in the near-term to support the increasing photovoltaic production capacity also being developed by DOE. The village power application represents such a potential market for photovoltaics. The price of energy for photovoltaic systems is compared to that of utility line extensions and diesel generators. The potential "domestic"' demand (including the 50 states of the union plus the areas under legal control of the U.S. government) is defined in both the goverment and commercial sectors. The foreign demand and sources of funding for village power systems in the developing countries are also discussed briefly. It is concluded that a near-term domestic market of at least 12 MW (peak) and a foreign market of about 10 GW (peak) exists and that significant market penetration should be possible beginning in the 1981--82 period.

Market conclusions: This study specifically addressed the market of village power applications in the United States and internationally. There are many areas where there is no central electrical generation capability on where the electrical distribution system is limited to the large cities. In these areas power is provided by small gasoline or diesel generator sets which are very expensive to operate from a fuel and maintenance point of view. Based on the cost of small scale electric power generation and the cost of extending utility lines, it was determined that for a load of 1 KW continuous, there are many applications in the United States that will be cost effective for PV systems when module prices are reduced to $6/W based on 1977 dollars. Internationally, the demand is even greater.

Domestically, the near-term market for Indian villages to be greater than 5.7 MW peak with market penetration beginning as early as 1979. Tire camps represent a near term market of 6 MW peak. Additionally, domestic markets for remote campsites, construction sites, surveying camps, and logging camps were identified but no market estimates were given.

The international market is much larger because many countries have not developed electrical distribution systems to supply rural areas. It is estimated that there are about 3 million villages that represent about 10,000 MV Peak as a near term market.

(ERA citation 03:037093)
DOE/NASA/1022-78/29

Utilization of Solar Energy in Developing Countries: Identifying Some Potential Markets

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AUTHOR: Hein, G. F.; Siddiqi, T. A.

STAR1620, Feb. 78, 13p., Rept No: NASA-TM-78964; DOE/NASA/1022-78/41,

Contract: E(49-28)-1022

Conf-Presented at the Ann. Meeting of the AM. Assoc. For the Advan. Of Sci., Washington, D.C., 12-17 Feb. 1978.

Abstract: The potential use of solar electricity generated from photovoltaic cells is examined for nineteen developing nations. Energy and economic profiles are summarized for each country. A comparison is made between the use of auto-generation and photovoltaics in a rural area of Haiti.

Market conclusion: Photovoltaic systems could provide energy for a 20W flourescent lighting system and a television more cost effectively than by using a gasoline generator in many developing countries. Distributed PV systems may offer significant advantages to developing centralized power systems. No estimate of market size was included.

N78-29578/9ST

Market Definition Studies for Photovoltaic Highway Applications.

Technical Marketing Associates, Inc., Concord, MA.

STAR1710, Dec. 78. 121p., Rept No: NASA-CR-159477; DOE/NASA/0040-78/1

Contract: DEN-3-40, DE-A101-79ET20485, EX-76-A-29-1022

Abstract: Prospects for solar electric power in applications related to highways within the continental United States are examined. Principal prospective users are found to be the highway departments of the various states. Economic analysis is employed to demonstrate that suitable applications can occur when powering apparatus such as signs, crossing signals, or instruments which consume less than 100 watts on the average, provided they are located at least one-half mile from existing utility power. Such applications are projected to occur two or three times per state per year. Attitudes of highway officials toward possible use of solar power are sampled and described. Although falling photovoltaic cell prices are expected to have little effect on sales potential here, methods for federal stimulation of this market are discussed.

Market Conclusions: This is a thorough and systematic market study. The emphasis is not on identifying the applications or the size of the market, but on the specifics of a very specific market (i.e., highway applications. This study identifies system parameters and costs of these application and identifies the requirement on a state by state basis. In addition to the technical aspects, the attitudes of the decision makers were investigated through almost 300 interviews. The specific markets are ranked based on a combination of objective and subjective data. This report serves as a basis for the development of specific product design and marketing efforts. Although this study was funded by the U.S. Government, it is much more typical of the type of information that is being developed in the corporate financed market studies. (ERA citation 04:036039)
DOE/NASA/0040-78/1, N79-19451/0ST

Market Definition Study of Photovoltaic Power for Remote Villages in the United States

Motorola, Inc., Phoenix, AZ.
*National Aeronautics and Space Administration, Washington, DC. AUTHOR: Ragsdale, C.; Quashie, P. STAR1811, Feb. 80, 71p. Rept No: NASA-CR-159800; DOE/NASA/0049-80/1 Contract: DEN3-49, DE-AI01-79ET-20485

Abstract: A grass roots evaluation of the market potential was carried out for photovoltaic applications in remote villages in the U. S. and its possessions. An estimate of almost 14 MWp available for conversion from a potential to a real market was defined. The total power potential was based on the energy needs of almost 400 sites reported by Federal agencies and inputs from over 100 Indian tribes. The methodology used, the results achieved, and some recommendations of how to convert this domestic market potential into a real market are detailed.

Market Conclusions: The objective was to assess the U.S. Market potential for photovoltaics in remote village applications from the point of view of a company engaged in the manufacturing and marketing photovaltaic modules and systems. This implies the following objectives: (1) identify types of villages most likely to represent the greatest potential market, (2) compile a list of potential near-term applications, (3) quantify the future market potential by type of application (4) identify barriers and obstacles which might inhibit the growth of the market, and (5) recommend action necessary to enhance the development of the market. The methodology was to systematically perform a literature search, perform personal interviews, send questionnaires to potential users, estimate loads, sort and tabulate data, and project the market size. Five major market segments were defined to be:

1) government agencies	- 3,000 KW
2) indian villages	- 10,000 KW
3) Alaskan villages	- 370 KW
4) Territories	- 500 KW
5) Commercial villages	- negligible
TOTAL	- 13,870 KW

This market is assumed to be small compared with remote villages in developing countries, partially due to the extensive electrification in the United States. Exhibits include load descriptions, questionnaires, categories, and lists of data collected as part of the project. The cost comparison assumed module costs of $10/W but the remaining economic parameters were not clearly defined.
N80-20812/7

Photovoltaic Water Pumping Applications: Assessment of the Near-Term Market

National Aeronautics and Space Administration. Lewis Research Center, Cleveland, Ohio.

AUTHOR: Rosenblum, L.; Bifano, W. J.; Scudder, L. R.; Poley, W. A.; Cusik, J. P.

STAR16 10, Mar. 78, 24p., Rept No: NASA-TM-78847; E-9566, Contract: E(49-26)-1022

Abstract: Water pumping applications represent a potential market for photovoltaics. The price of energy for photovoltaic systems was compared to that of utility line extensions and diesel generators. The potential domestic demand was defined in the government, commercial/institutional and public sectors. The foreign demand and sources of funding for water pumping systems in the developing countries were also discussed briefly. It was concluded that a near term domestic market of at least 240 megawatts and a foreign market of about 6 gigawatts exist.

Market conclusions: This report identifies several pumping market areas and describes some of the demonstration projects that have been performed. The relative costs of system operation are compared and it was determined that for pumping applications in the 1KW range, PV is competative with a 5 mile power line extension at an array cost of $6/w and in mountaineous areas, at $10/w for domestic markets. In the international market PV is competative with diesel power in the 1981 time frame. The markets identified are:

Waste treatment and drainage

1. Sanitary systems
2. Land drainage
3. Industrial waste and process water

Potale water

Crop irrigation

This report also concluded that there was very little awareness of PV as an option in the international market, so that it will be necessary to conduct demonstration projects to develop user confidence in the system. This report includes a list of contacts, and the economic methodology used for the study.

POTENTIAL DOMESTIC DEMAND

Waste treatment and Drainage	Demand-MWP
- Sanitary systems	110
- Industrial waste	None near-term
- Land drainage	100
Potable water	22
Crop irrigation	22
- Potential Foreign Demand	
Crop irrigation	6,000
- Potable water	70

N78-19644/1ST

III. RELATED STUDIES

The following studies support photovoltaic terrestrial application market studies.

Conceptual Design and System Analysis of Photovoltaic Systems. Volume III. Appendices. Final Report, June 1975--March 1977 General Electric Co., Philadelphia, Pa. Space Div.

*Department of Energy.

GRAI7816, 19 Mar 77, 569p., Contract: EY-76-C-04-3686

Abstract: The objective of this analysis is to evaluate the economic worth of photovoltaic generating units (PEPS) to electric utilities using electric utility industry evaluation practices that had already been established. Ths basic methodology is to use the levelized busbar energy cost (LBC) to compare the various technical concepts and compare the costs with conventional alternatives. The investigation of terrestrial PV systems considered the technical and economic feasibility for systems in three size categories: a small system of about 12 kW peak output for on-site residential use; a large 1500 MW central power plant contributing to the bulk energy of a utility system power grid; and an intermediate size system of about 250 kW for use on public or commercial buildings. In each category, conceptual designs were developed, performance was analyzed for a range of climatic regions, economic analyses were performed, and assessments were made of pertinent institutional issues. The report consists of three volumes. Volume I contains a Study Summary of the major study results. Volume II contains the detailed results pertaining to on-site residential photovoltaic systems, central power plant photovoltaic systems, and intermediate size systems applied to commercial and public buildings. This volume contains supporting appendix material.

Market Conclusions: This study did not attempt to estimate the market penetration into the utility industry, but it did systematically identify the applications and load characteristics of the present applications for conventional utility power.
(ERA citation 03:028007) ALO/3686-14(V.3)(App.)

Photovoltaic Systems Concept Study. Final Report

Spectrolab, Inc., Sylmar, Calif.

*Department of Energy.

GRAI7818, Apr. 77, 212p., Contract: EY-76-C-04-2748

Abstract: This report documents the work performed in the conceptual design and systems analysis of three sizes of photovoltaic solar electric power systems. Conceptual system designs were developed for a single family residence, a central station power plant and for two-on-site intermediate systems (shopping center and commercial retrofit). The following appendices are included: economic theory, electric utilities, and peak load pricing; evaluating the total cost of an on-site solar energy system; derivation of PEPS cost model; PEPS economic analysis model; scenarios; the effect of governmental "subsidies" on the nuclear power industry; discussion of energy industry subsidies; extension of the Hottel-Whillier-Bliss model to the analysis of combined photovoltaic/thermal flat plate collectors; analysis of solar-augmented rock-bed/heat pump system; TRNSYS results for Washington, D.C. residence with air collectors, rock-bed storage, and parallel Airesearch heat pump; tabulation of electrical loads for Phoenix, Riverside, and Cleveland using a simplified hourly method; evaporative air coolers; cooling efficiency and electrical consumption; and Hoover Dam operation.

Market Conclusions: This study does not attempt to determine the size of the market, but rather to develop technical concepts that will satisfy the demands of specific markets. (ERA citation 03:032893)
ALO/2748-12(V.5)

Systems Descriptions and Engineering Costs for Solar-Related Technologies. Volume VIII. Photovoltaic Central Power Systems

MITRE Corp., McLean, VA. METREK Div.

*Department of Energy.

AUTHOR: Cherdak, A.

GRAI7906, Jun. 77, 108p., Contract: EX-76-C-01-2322

Abstract: Based upon the results of ERDA-sponsored study programs, capital and operating and maintenance cost estimates have been derived for a variety of photovoltaic central power systems. The ERDA studies developed conceptual designs for systems without storage capability. These results were modified to reflect consistent technological and costing bases. Using these results, a series of generic photovoltaic system designs were developed with and without energy storage. Estimated costs for these systems show that the structure required to support the photovoltaic collectors is expected to be a major portion of system costs.

Market Conclusions: This study addresses the costs of various PV system concepts but does not extrapolate the results to estimate the potential market implications. (ERA citation 03:056706)
MTR-7485(V.8)

Application Analysis of Solar Total Energy to the Residential Sector. Quarterly Technical Status Report, July 1--September 30, 1977

Institute of Gas Technology, Chicago, IL.

*Department of Energy.

AUTHOR: Whaley, T.; Yudow, B.; Malik, N.; Gamze, M.; Foster, B. GRAI7906, Oct. 77, 172p., Contract: EG-77-C-04-3787

Abstract: A solar total energy system (STES) is defined as an energy system designed to maximize the efficient use of collected solar energy by supplying both the low-grade (low-temperature thermal) and high-grade (electrical and/or mechanical) energy needs of selected applications. ERDA's Solar Total Energy Program is concerned primarily with those solar total energy systems that use heat engine or photovoltaic devices to produce electricity (and/or mechanical work) and apply the residual thermal energy from the conversion process to some useful purpose. The solar total energy is backed up and supplemented to the extent required by conventional fossil-fuel-derived energy for periods when solar-derived energy is inadequate. This project will analyze the application of solar total energy to appropriate segments of the residential sector, determine the market penetration potential for STE systems, and develop criteria for selecting suitable demonstration sites throughout the United States.

Market Conclusion: The objective is to assess the extent and rate to which solar total energy systems can penetrate energy markets in residential sectors in the intermediate term and to project market penetration to the year 2020. The specific emphasis of this study is on the long term implications of residential total energy systems and their interface with the utility system. Much of the project deals with the defining the loads that are presently supplied by conventional utilities and identifying systems that use solar energy that can meet those demands. Another objective is to produce and evaluate four conceptual designs for solar total energy systems that have maximum potential for significant penetration of residential energy market. The last objective is to develop suitable criteria for selecting demonstration sites to best promote early market penetration for total energy systems, some of which will include photovoltaics. (ERA citation 04:000438)
TID-28105

Analysis of Investment Alternatives to Stimulate Development and Technology Transfer for Energy Technologies. Solar Photovoltaics: A Case Study

TRW, Inc., McLean, VA. Energy Systems Planning Div.

*Department of Energy.

GRAI7919, Sep. 78, 151p., Contract: ET-78-C-05-5670

Abstract: Based on each of the five distinct PV plant designs, a manufacturer's analysis of the return-on-investment that could be achieved by building a plant with the aid of each of six types of incentives was simulated. Descriptions and results of these analyses are presented. The general decision tree analysis in which other options are considered is illustrated. Using the future residential market as a testbed, and for a variety of types or applications within the residential market, the significance of the balance-of-system costs issue is addressed in some detail. A survey of the photovoltaic industry as it existed in 1978 is presented and the potential impact of incentives on the future competitiveness of the industry is discussed. Details of the methodology used to simulate corporate responses to inventive programs and computational details for balance-of-system costs are presented. This report concentrates on the impact of government incentive options primarily on the Presidential P.V. market. (ERA citation 04:036049)
TID-28968

Photovoltaic Tests and Applications Project Progress Report for April 1976--June 1977

National Aeronautics and Space Administration, Cleveland, OH. Lewis Research Center.

*Department of Energy.

GRAI7917, Nov. 78, 91p., Rept No: NASA-TM-79018, Contract: EX-76-A-29-1022

Abstract: The activities and accomplishments of the Photovoltaic Tests and Applications Project during the period April 1976 through June 1977 are summarized. Results of efforts to identify potential near-term photovoltaic applications and users are discussed, including the outcome of an extensive survey of Federal government agencies. The status of application experiments is presented, with descriptions being given of 34 experiments either in operation or being readied for operation. Various general engineering efforts are reported, including the design and construction of a photovoltaic Systems Test Facility at LeRC. Efforts to develop a high efficiency 10 kVA self-commuted inverter and controller specifically designed for photovoltaic systems are also discussed. The results of a wide variety of activities in the area of photovoltaic measurements and standards are related, including performance measurements, endurance testing, design of a standard solar reference cell, and the development of terrestrial measurement procedures. Documents generated by the Project during the reporting period are listed in an Appendix. (ERA citation 04:025881)
DOE/NASA/1022-78/42

Summary of Application Analysis for Photovoltaic Systems

Sandia Labs., Albuquerque, NM.

*Department of Energy.

AUTHOR: Jones, G. J.; Watkins, J. L.

GRAI8005 1979, 12p. Rept No: CONF-790138-1 Contract: EY-76-C-04-0789

Abstract: The results of the studies to date indicate cost effectiveness of consumer-owned photovoltaic systems in many regions in 1986 and everywhere by 2000, providing DOE price goals are met. Battery storage should be considered an integral part of only smaller (residential, remote) photovoltaic systems. The economic justification of battery storage in larger systems, especially utility owned ones, is relatively independent of the presence of the photovoltaic array. The greatest general area of uncertainty in all sectors is the utility-customer interface for consumer owned systems, and the worth of the photovoltaic system to the utility for utility owned systems.

This is a summary of work that has been done in the photovoltaic system analysis area, as well as a description of current and planned activities. The five application sectors considered are: remote, residential, service/commercial/institutional/ industrial, agricultural, and central power.
(ERA citation 04:036046)
SAND-78-0980C

Criteria for an Ideal Solar Photovoltaic Powered Industry

Wizard Research and Development Group, Inc., Washington, DC.

*Department of Energy.

GRAI8004, Jun 79, 74p.

Contract: ET-78-X-01-5433

Abstract: A study based on the results of a literature survey on the application of solar photovoltaic energy and the use of energy in the Primary Metals Industries is given. A criteria is outlined for an ideal solar photovoltaic powered industry and the Primary Metals Industries is evaluated with respect to this criteria. Some of the major findings of this report are: (1) The most important requirements of an ideal solar photovoltaic powered industry are the ability to use dc electrical power, ability to be located in Southern California or the Southwestern US and ability to do without power for extended periods of time. (2) The costs of varying from the ideal are most severe with respect to the loss of power element of the criteria. (3) Although most of the industries in the Primary Metals group use tremendous amounts of electrical energy, the general requirements of an uninterruptable power source makes them less than ideal users of photovoltaic energy. (4) It appears to be both technologically and economically feasible to develop processes which would make at least four of the seven members of the Primary Metals Industries ideal solar photovoltaic powered industries. (ERA citation 04:052805)
HCP/T5433-01

Application Analysis of Solar Total Energy Systems to the Residential Sector. Volume I, Executive Summary. Final Report

Institute of Gas Technology, Chicago, IL.

*Department of Energy.

GRAI8013, Jul. 79, 43p. Contract: EG-77-C-04-3787

Abstract: The objectives of the program were to define solar total energy systems (STES) that are suitable for the residential sector and to assess the market penetration potential of these systems. Residential market segments were determined from data on housing inventory and building parameters selected for representative units of single-family detached homes, townhouses, low-rise apartments, and high-rise apartments. After dividing the country into regions based on climate, insolation, energy costs, and population, electrical and thermal energy requirements were determined for each building type in each region. In keeping with the 50 kWe (or greater) constraint, single-family detached homes were considered only as groups of houses connected to a central STE system of 100-kW electric generating capacity. After consideration of various collector types, candidate collectors deemed most appropriate to residential application of solar total energy systems were evaluated for performance in different regions and compatibility with appropriate energy conversion devices. Conceptual designs were then generated for suitable combinations of collectors and energy conversion devices, and their hourly performance evaluated by computer simulation over a one-year period. Results were used to determine system economics and to assess their potential for market penetration in the residential sector, based on projected costs and availability of competing energy sources in the 1985 to 2020 time frame. Although none of the systems were judged to have positive market penetration potential in the time frame of the study, sensitivity studies indicated those circumstances that would be required for market penetration feasibility.

Market conclusions: This study addressed intermediate and long term market. (ERA citation 04:052870) ALO-3787-1(Exec.Sum.)

Objectives and Strategies of the International Photovoltaic Program Plan.

Solar Energy Research Inst., Golden, CO.

*Jet Propulsion Lab., Pasadena, CA., *Department of Energy.

AUTHOR: Costello, D.; Posner, D.; Koontz, R.; Heiferling, P.; Carpenter, P., GRAI8013,

Jul. 79, 43p., Contract: EG-77-C-01-4042

Abstract: The Solar Photovoltaic Energy Research, Development, and Demonstration (RD and D) Act of 1978 calls for the Secretary of the US Department of Energy (DOE) to prepare a plan to demonstrate photovoltaic systems in other nations and to facilitate the widespread use of these systems. The objective of the International Photovoltaic Program Plan, the strategies that will be used in the plan, and the approach that is being taken to prepare the plan are described. Background on photovoltaic technology and markets and the DOE domestic photovoltaic effort is also provided. The International Photovoltaic Program Plan will complement the DOE domestic activities to stimulate international markets. A number of national and international benefits could result if the objective of accelerating the widespread use of photovoltaic systems in international markets is realized. A primary benefit is that foreign markets may help stabilize the US photovoltaic industry and foster its expansion. Other benefits include contributions to the advancement of developing countries, reductions in world oil imports, and improvements in the US balance of trade. Strategies to be addressed in the plan are photovoltaic system demonstrations, systems development, information gathering and dissemination, financial incentives, and administrative actions. A critical aspect of the plan will be the coordination of selected programs and the monitoring and assessment of the plan's results. Analyses of international markets, international financial institutions, foreign competition, international marketing experiences of other US industries, and system development needs have been initiated to support the plan.

(ERA citation 04:056240)
SERI/TR-52-250

A Survey of Photovoltaic Systems, Alabama Univ., Huntsville.
STAR1806, Aug. 79, 213p., Rept No: NASA-CR-150696
Contract: NAS8-31293

Abstract: Solar photovoltaic manufacturers and suppliers are listed. Data sheets on specific products and typical operating, installation, or maintenance instructions and procedures are appended.
N80-15563/3

International Photovoltaic Program. Volume 2: Appendices

Jet Propulsion Lab., Pasadena, CA.

*National Aeronautics and Space Administration, Washington, DC.

AUTHOR: Costello, D.; Koontz, R.; Posner, D.; Heiferling, P.; Carpenter, P.

STAR1817, Dec. 79, 218p., Rept No: NASA-CR-163339

Contract: EG-77-C-01-4042 Prepared Jointly with Midwest Research Inst., Golden, Colo., Massachusetts Inst. Of Technol. Cambridge and Illinois Inst. Of Technol., Chicago.

Abstract: The results of analyses conducted in preparation of an international photovoltaic marketing plan are summarized. Included are compilations of relevant statutes and existing Federal programs; strategies designed to expand the use of photovoltaics abroad; information on the domestic photovoltaic plan and its impact on the proposed international plan; perspectives on foreign competition; industry views on the international photovoltaic market and ideas about the how US government actions could affect this market; international financing issues; and information on issues affecting foreign policy and developing countries.
N80-26859/2

Application Analysis and Photovoltaic System Conceptual Design for Service/Commercial/Institutional and Industrial Sectors. Volume II. Technical Report. Final Report

Research Triangle Inst., Research Triangle Park, NC.
*Department of Energy, Washington, DC. AUTHOR: Whisnant, R. A.; Morrison, C. B.; Staffa, N. G.; Alberts, R. D.
GRAI8016, Dec. 79, 219p. Contract: EY-76-C-04-0789

Abstract: It is the objective of this study to examine the nature of potential applications of photovoltaics in the SCII sectors and to suggest the most appropriate areas for development of photovoltaic markets within those sectors. The target market is industries that require systems of 25 KW and greater. The analysis consists of four tasks: (1) The two-digit Standard Industrial Classification Codes have been used to describe the universe of applications that must be considered. Data on the attributes of these applications that are germane to solar photovoltaic systems application have been identified and acquired, and the figure of merit, utilizing the collected data, that indicates the relative photovoltaic potential for displacement of conventionally generated electricity of the various applications has been devised and applied. (2) The expected profitability of photovoltaic application is determined from the discounted future costs of conventional energy sources, capital costs, and projected operating and maintenance costs over the life of the system. This is combined with the energy consumption of the application to obtain an estimate of the energy market potential. (3) The application ranking and subjective evaluations of market size, diversity, and public exposure are used to select five applications and their locations for design of a suitable photovoltaic system. (4) For each of the selected applications, the various relevant characteristics are identified, potential photovoltaic system configurations are identified, and performance and economic models are used to design a representative system. The design of the selected system is described and documented with schematics, drawings, specifications, and cost estimates.

Market Conclusions: This study provides an excellent base for estimating the load characteristics of large energy consuming sectors. However, since the level of detail is limited to the two-digit SIC code, very little information is directly applicable to a particular industry. An example industry was selected based on a system design for a selected industry within each SCIT sector. The emphasis is on the utility market which is intermediate on long-term in nature. This study had very strong utility participation and therefore, load data relative to the market sectors is unique among market studies that have been done to date.

(ERA citation 05:015239) SAND-79-7020(V.2)

Central Station Applications Planning Activities and Supporting Studies

Aerospace Corp., El Segundo, CA.

*National Aeronautics and Space Administration, Washington, DC. Final Report.

AUTHOR: Leonard, S. L.; Siegel, B.

STAR1817, Apr. 80, 117p., Rept No: NASA-CR-163042; JPL-9950-372

Contract: JPL-955434

Abstract: The application of photovoltaic technology in central station (utility) power generation plants is considered. A program of data collection and analysis designed to provide additional information about the subset of the utility market that was identified as the initial target for photovoltaic penetration, the oil-dependent utilities (especially muncipals) of the U.S. Sunbelt, is described along with a series of interviews designed to ascertain utility industry opinions about the National Photovoltaic Program as it relates to central station applications.

Market Conclusions: Early estimates indicated that photovoltaic system costs must be in the $1.10-1.30/W range in order to be competitive in utility applications. However, as a result of the sharply increasing oil prices, it was estimated that by the late 1980s, Photovoltaic systems in the cost range $1.50-2.00/KW. Time frame considered is early 1990s.
N80-26784/2

Photovoltaic System Costs Using Local Labor and Materials in Developing Countries

Georgia Inst. of Tech., Atlanta. Engineering Extension Lab.

*National Aeronautics and Space Administration, Washington, DC.

AUTHOR: Jacobson, E.; Fletcher, G.; Hein, G. STAR1816, 20 May 80, 60p.,

Rept No: NASA-CR-163218

Grant: NSG-3297

Abstract: The use of photovoltaic (PV) technology in countries that do not presently have high technology industrial capacity was investigated. The relative cost of integrating indigenous labor (and manufacturing where available) into the balance of the system industry of seven countries (Egypt, Haiti, the Ivory Coast, Kenya, Mexico, Nepal, and the Phillipines) was determined. The results were then generalized to other countries, at most levels of development. The results of the study imply several conclusions: (1) the cost of installing and maintaining comparable photovoltaic systems in developing countries is less than in the United States; (2) skills and some materials are available in the seven subject countries that may be applied to constructing and maintaining PV systems; (3) there is an interest in foreign countries in photovoltaics; and (4) conversations with foreign nationals suggest that photovoltaics must be introduced in foreign markets as an appropriate technology with high technology components rather than as a high technology system. N80-25785/0

Solar Market Studies: Review and Comment

Solar Energy Research Inst., Golden, Co.

AUTHOR Vories, R., Strong, H.

SERI/SP-434-475, Contract ACO2-77CH--178, STD-58b, 59 pp, May 1980

Abstract: This report summarizes and comments on relevant solar energy market surveys and related studies to provide a basis for determining areas requiring additional research and possible policies and actions to aid in rapid adoption of solar technologies. Thirty-two studies are discussed. The first 19 studies directly assess the market for residential use of solar domestic hot water, space, and pool heating. Studies 20 and 23 examine the financial incentives and financial institutions in the expanding solar market. Study 24 considers energy and low-income people. Studies 25 and 26 assess market sizes for photovoltaic systems and wind machines. Studies 27 to 30 are not surveys per se, but represent secondary source and modeling efforts to gain understanding of the solar marketplace. Studies 31 and 32 present the Canadian perspective on the market feasibility of solar energy systems. Many of the studies contained flaws of concept and/or method to a degree that would bring into question the credibility of individual findings but, taken as an aggregate, they provide a useful compendium of opinion about present and potential solar energy users.

Market Conclusions: This report was a review of market studies over the whole solar market. There was only one PV market study reviewed (Photovoltaic power Systems Market Identification and Analysis, BDM, Nov. 1978).

CHAPTER IV
MARKETS FOR PHOTOVOLTAICS AS AN INDUSTRIAL POWER SOURCE

The industrial market for photovoltaic systems is divided into two general categories, industrial power applications and component applications. Industrial power applications are those applications where the industry uses photovoltaic systems to supply power to the industry. This chapter addresses only those potential markets for photovoltaic power systems as sources of industrial power, while the following chapter deals with component applications.

Techniques and data sources were developed that could be used to identify the industries for which large applications of PV power will be cost effective as PV costs are reduced. In order to identify potential PV markets, inputs were provided by published literature, the Industrial Applications and Policy Branch of SERI, and the research staff at Georgia Tech.

From market identification studies a limited criteria base was developed that could be used to evaluate and define types of industries that will use PV to power the manufacturing process as well as specific applications that may be listed in these studies. The information contained in the market studies was used to help guide later phases of the criteria identification and also was incorporated directly into data obtained from other sources.

Most of the market studies performed to date have concentrated on near term applications, which are mostly small scale systems or are isolated system applications. Therefore it was necessary to expand on the criteria base to evaluate other likely applications for PV power. As one method a conference was conducted with members of the Georgia Tech faculty that have experience in PV, solar energy, and industrial energy use. The conference was organized around a questionnaire that was used to direct the responses to certain areas. When the meeting was conducted members in turn responsed to each question and then each question was discussed by the group. As a result of the discussion, some of the responses were combined to reflect the consensus of the group.

The following questions were used to provide direction for the conference.

1 - Initial Response

Based on your present knowledge of photovoltaics and photovoltaic energy systems, what do you think are the three most important technical criteria that an industry must have to be able to use photovoltaic energy?

2 - Insolation/Meteorological

What are the characteristics of an industry that might use photovoltaic energy, with respect to insolation and meteorological conditions?

3 - Location

What criteria relevant to location would an industry have that would use a photovoltaic energy system.

A. From a national point of view.

B. From a local point of view.

4 - Economic

What economic criteria would be relevant to an industry that would use photovoltaic energy?

5 - Institutional

What institutional criteria will influence the use of photovoltaic energy by industries?

6 - Competing Energy Sources

What types of competing energy sources will encourage or discourage the use of photovoltaic energy?

A. Encourage B. Discourage

7 - Follow-up

List any other criteria that are important to the development of industrial applications of photovoltaic energy?

Participants received the questionnaires before the meeting time. At the meeting each participant discussed responses to each question, which were pursued to develop additional criteria not included in the original responses to the questionnaire. Appendix A describes the compilation of results from the questionnaire, the discussions, available literature, and a limited amount of background and explanatory information.

The results of this conference and the literature search described in Chapter III were combined to generate a composite list of criteria that could be used to identify industries that may possibly use PV power. The composite list was then sent to the Industrial Applications and Policy Branch at the Solar Energy Research Institute for comment and generation of additional criteria. The result was a list of market factors that were divided into three categories:

A) Market factors for industries by four-digit Standard Industrial Classification (SIC) Code.
B) Geographical market factors.
C) Site specific markets factors.

The factors included in group A were used to identify industry types by four-digit SIC codes. Group B factors were used to identify geographical regions. The candidate companies can be further defined by the intersection of groups A and B and by using existing data. The market factors in group C were very specific and required knowledge about companies that can only come from site visits or phone calls to each candidate industry. Application of group C factors was beyond the scope of this project.

Through this process the list of market factors in Table IV-1 was generated. These market factors were partially selected with the availibity of data in mind. Appendix B describes the data sources for each of the market factors in Groups A and B.

The data bases listed in Appendix B permit the use of quantitative methods to indicate potential industries for PV applications. This is accomplished by selecting parameters that are directly related to the market factor under investigation, and using those parameters to rank industries by catagory. In some cases, data are used directly as the basis for ranking while in other casis it is desirable to combine two or more data sets through simple mathematical operations. In still other cases it is not practical to use quantitative data as the basis for the identification of industries that are high potential markets for PV power, so that more qualitative techniques must be employed. The following paragraphs discuss some of the ranking techniques that may be used for data sets associated with market factors listed in Table IV-1, as well as some examples of the type of data that are available.

Since the type of available data vary significantly by market factor, the order in which the market factors are addressed can significantly reduce analysis time.

Table IV-1

MARKET FACTOR CATEGORIES
FACTORS THAT IDENTIFY INDUSTRIAL USERS
OF PHOTOVOLTAIC POWER

A. Industrial Markets by Four-Digit SIC

- A1. Use of D. C. power
- A2. Energy consumption compatible with availability of solar radiation (i.e., both diurnal and annual).
- A3. Energy intensive (e.g., a large ratio of energy costs to value added)
- A4. Large electrical load
- A5. Currently generating electricity for own use
- A6. Often are remotely sited from the utility grid
- A7. Located in geographically favorable areas (see B)

B. Geographical Markets

- B1. Output of different types of PV arrays (e.g., concentrating vs. non-concentrating)
- B2. Utility service areas where industrial electricity rates are high
- B3. States with substantial financial incentives for PV systems in industry
- B4. High industrial growth regions
- B5. Areas with stringent air quality regulations and restrictions
- B6. Areas where utilities and regulatory agencies are supportive of PV systems

C. Industry Type and Specific Plant Markets Through Site Visits

- C1. Management attitudes favorable to PV systems
- C2. Available and unobstructed roof and/or land area
- C3. Low land cost
- C4. Plant to be located at a remote site
- C5. Clean micro and macro air quality
- C6. Long payback periods and acceptable to key decision-makers
- C7. Availability of substantial capital
- C8. Community attitudes about solar energy
- C9. Previous adoption of a high level of potential energy conservation efforts
- C10. New plant construction and/or relocation is planned
- C11. All of the criteria in Categories A. and B.

As an example, selection of industries based on a market factor such as "A.6 Often remotely sited from utility grid" is difficult to accomplish through the use of quantitative techniques, because for each industry specific knowledge is required that is not available in a single data base. However, by reducing the number of industries under consideration through the analysis of other more quantitative market factors, it is possible to narrow the number of industries for sublequent in-depth evaluation.

Based on presently available data, the following order is recommended. The market factor numbers refer to Table IV-1.

(A3) Energy-intensive industries can be identified and ranked on the basis of the quotient of the electrical energy consumption divided by value added. Such data are available on computer tape on a state by state basis, and some of this analysis has already been performed. The results of the application of this ranking will be the identification of industries for which energy costs are a large part of the product cost. Moreover, multiplying this quotient by the local cost of energy permits regional differences in the cost of energy to be considered.

(A4) Industry groups that have large electrical loads can also be identified with the data base that is used to determine energy intensiveness.

(A1) The industries indicated in factors A3 and A4 can be compared with recently published reports to identify industry groups that have applications for D. C. power.

(A2,A5,A6) The remaining industry groups must be analyzed on an individual basis in order to determine the compatibility (present of potential) between the energy consumption of the industry group and the availibity of solar energy.

The result of successive application of the market factor ranking criteria will result in the identification of a relatively small number of industry groups that represent the the highest potential markets for photovoltaic power systems.

The next step is the identification of areas of the country where potential markets for PV power systems are likely to be located. This will be done through the use of the market factors listed in group B in Table IV-1.

(B1) The performance characteristics of various types of PV modules can be predicted based on the geographical distribution of solar radiation. This will

result in the identification of regions that have very high expected PV power output.

(B2) Data are also available to identify regions of the country that have high electrical energy costs. Electricity costs are an important factor, and the product of the energy cost and available solar energy provides a useful ranking criterion.

(B4) Regions that are experiencing rapid industrial growth will further narrow the regions of the country for which new PV applications are most likely.

(B3, B5, B6) Institutional and regulatory considerations will also assist in the identification of areas of the country that represent potential markets.

After these analyses have been performed, camputerized data bases can provide lists of campanies by catagories and geographical regions of the country. Further identification of potential markets for photovoltaic power system markets can continue through direct cantact with specific industries via phone, letter, or site visits.

It was beyond the scope of this project to collect and analyze all of the data previously mentioned. However, a few data catagories were selected, data were collected, and a limited amount of analysis was performed. In this context, the following data and analysis is presented to illustrate the type of data that are available and the types of analyses that may be performed.

The following market factors were selected from Table IV-1 to serve as examples:

A3. Energy intensive (large energy cost to value added ratio).
B1. Output of PV arrays (eg., concentrating vs. nonconcentrating)
B2. Utility service areas where industrial electricity rates are high.

The U.S. Census Bureau collects and analyzes data describing the industrial sector of the United States economy. These data are organized into the Standard Industrial Classification (SIC). Table IV-2 lists two-digit and four-digit SIC codes used in these examples. These codes are used to reference all data entries. The manufacturing organizations are in classifications 20 through 39.

Table IV-2

STANDARD INDUSTRIAL CLASSIFICATION CODES

SIC Codes	DESCRIPTION
20	Food and Kindred Prpducts
2074	Cottenseed Oil Mills
21	Tobacco Manufactures
2141	Tobacco Stemming and Redrying
22	Textile Mill Products
2296	Tire Cord and Fabric
23	Apparel and Other Textile Products
2371	Fur Goods
24	Lumber and Wood Products
2499	Miscellaneous Wood Products
25	Furnature and Fixtures
2519	Household Furniture, NEC
26	Paper and Allied Products
2661	Building Paper and Board Mills
27	Printing and Publishing
2754	Commercial Printing-Gravure
28	Chemicals and Allied Products
2813	Industrial Gases
29	Petroleum and Coal Products
2911	Petroleum Refining
30	Rubber and Miscellaneous Plastic Products
3021	Rubber and Plastic Footwear
31	Leather and Leather Products
3111	Leather Tanning and Finishing
32	Stone, Clay, and Glass Products
3241	Cement, Hydraulic
33	Primary Metal Industries
3334	Primary Production of Aluminum
34	Fabricated Metal Products
3497	Metal Foil and Leaf
35	Machinery, Except Electrical
3562	Ball and Roller Bearings
36	Electrical and Electronic Equipment
3624	Carbon and Graphite Products
37	Transportation Equipment
3714	Motor Vehicle Parts and Accessories
38	Instruments and Related Products
3824	Totalizing Fluid Meters and Counting Devices
39	Miscellaneous Manufacturing Industries
3996	Linoleum, Asphalted-Felt-Base, and Other Hard Surface Floorings, NEC

Note: Each Four-digit sub-group is the most energy-intensive in the Two-digit group.

Energy Intensiveness

As part of the Census of Manufacturers, there are a number of economic parameters that are collected for each four-digit SIC category on a state by state basis every five years. These economic parameters include the value added. These data were collected for 1976. Although these data have been published for the individual states and are available on computer tape, the synopsis has not yet been published (but should be available this year). As an example of how these data can be used, Table IV-3 contains the electrical energy (in Btu's) per dollar of value added (in 1976 dollars) for selected two- and four-digit SIC's. The data are presented for the highest four-digit catagory in each of the two-digit industrial catagories, as well as the average for each of the two-digit catagories. As might be expected, the SIC 33 group of primary metals industries is the most energy intensive. However, there are several other specific categories that have relatively high electric energy consumption. By selecting only the most energy intensive four-digit industry groups for further consideration, the application of future criteria is greatly simplified.

Energy Production Potential

The power output from PV arrays depends on the location, the meteorology, and the specific characteristics of two basic types of PV arrays. One type uses flat plate collectors; its output depends on the total radiation striking the flat plate surface. The amount of energy that will be available from such an array as a function of geographical location is illustrated by a map of the total solar radiation that strikes a horizontal surface as shown in Figure IV-1. The Southwestern United States has the best potential for an array of this type. A second type of array is made up of concentrating collectors. This type of collector requires direct radiation to function. As a result, the map shown in Figure IV-2 provides a direct visual representation of the best geographical areas for concentrating collectors. Again the southwest has the highest potential while the northeast is shown as a much less favorable location for the use of concentrating type collectors.

Utility Service Areas Where Industrial Electricity rates are High

One of the factors that is very important in the determination of the cost effectiveness of PV is the cost of competing energy sources. Since PV supplies

Table IV-3

ENERGY INTENSIVENESS
BY INDUSTRY SECTOR (1976)

SIC Codes	Electricity Energy Purchased: Quantity (Million Kw-hrs.)	Electricity Energy Purchased: Cost (Million Dollars)	Value Added by Manufacture Million Dollars	Electricity (in Btu's) per Value Added
20	39,040.8	903.4	52,759.7	2,524.7
2074	513.2	11.3	128.7	13,209.0
21	1,122.4	26.7	4,127.8	920.6
2141	347.7	8.8	227.5	5,274.7
22	28,276.6	591.0	14,495.1	6,595.3
2296	752.3	15.2	201.6	12,400.8
23	7,119.9	176.2	16,859.9	1,364.2
2371				4,010.7
24	16,158.4	307.2	13,453.6	3,939.5
2499	2,570.2	54.0	1,142.2	22,275.3
25	4,100.1	104.7	7,370.3	1,831.7
2519	149.2	3.6	103.4	3,868.5
26	43,555.2	774.1	20,603.7	7,197.7
2661	1,416.0	27.5	240.0	20,416.7
27	10,377.1	268.0	27,647.3	1,251.4
2754	400.4	9.5	496.2	2,619.9
28	146,545.4	2,301.4	51,407.5	9,652.3
2813	11,364.2	198.4	644.7	58,787.0
29	27,973.2	484.0	13,168.9	7,183.6
2911	26,461.7	443.9	11,409.6	7,861.8
30	20,248.9	476.0	15,950.3	4,225.6
3021	193.1	5.6	309.5	13,513.5
31	1,522.7	40.1	3,558.6	1,433.2
3111	375.6	10.6	512.1	2,302.8
32	29,165.8	633.6	16,772.9	5,950.1
3241	9,136.7	185.1	1,461.3	21,350.9
33	148,250.1	2,234.6	34,181.9	14,738.8
3334	58,776.7	470.9	1,465.9	136,844.3
34	25,180.8	629.8	39,145.0	2,230.2
3497	308.1	7.0	177.7	6,190.2
35	28,489.9	693.2	57,357.0	1,663.3
3562	1,234.8	28.9	1,327.5	3,163.8
36	23,888.7	561.3	41,746.2	1,928.3
3624	1,703.6	28.9	399.0	14,536.3
37	29,712.1	722.0	55,657.3	1,811.1
3714	10,169.6	246.2	13,709.4	2,509.2
38	5,321.6	141.6	16,386.2	1,080.2
3824	166.4	4.0	352.1	1,704.1
39	4,114.8	110.3	8,821.9	1,439.6
3996	188.8	4.1	270.1	2,221.4

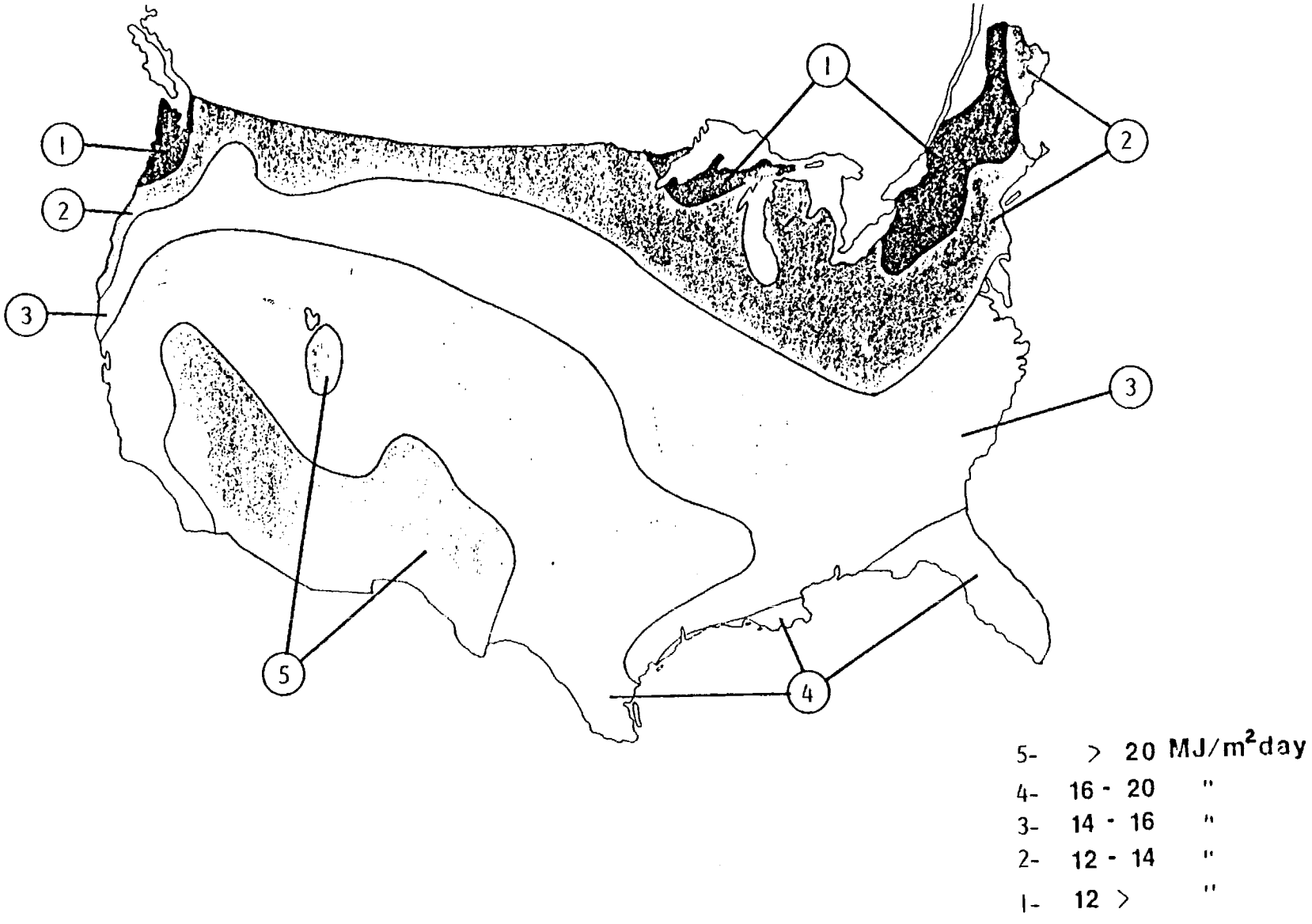

Figure IV-1. Total Solar Radiation on a Horizontal Surface

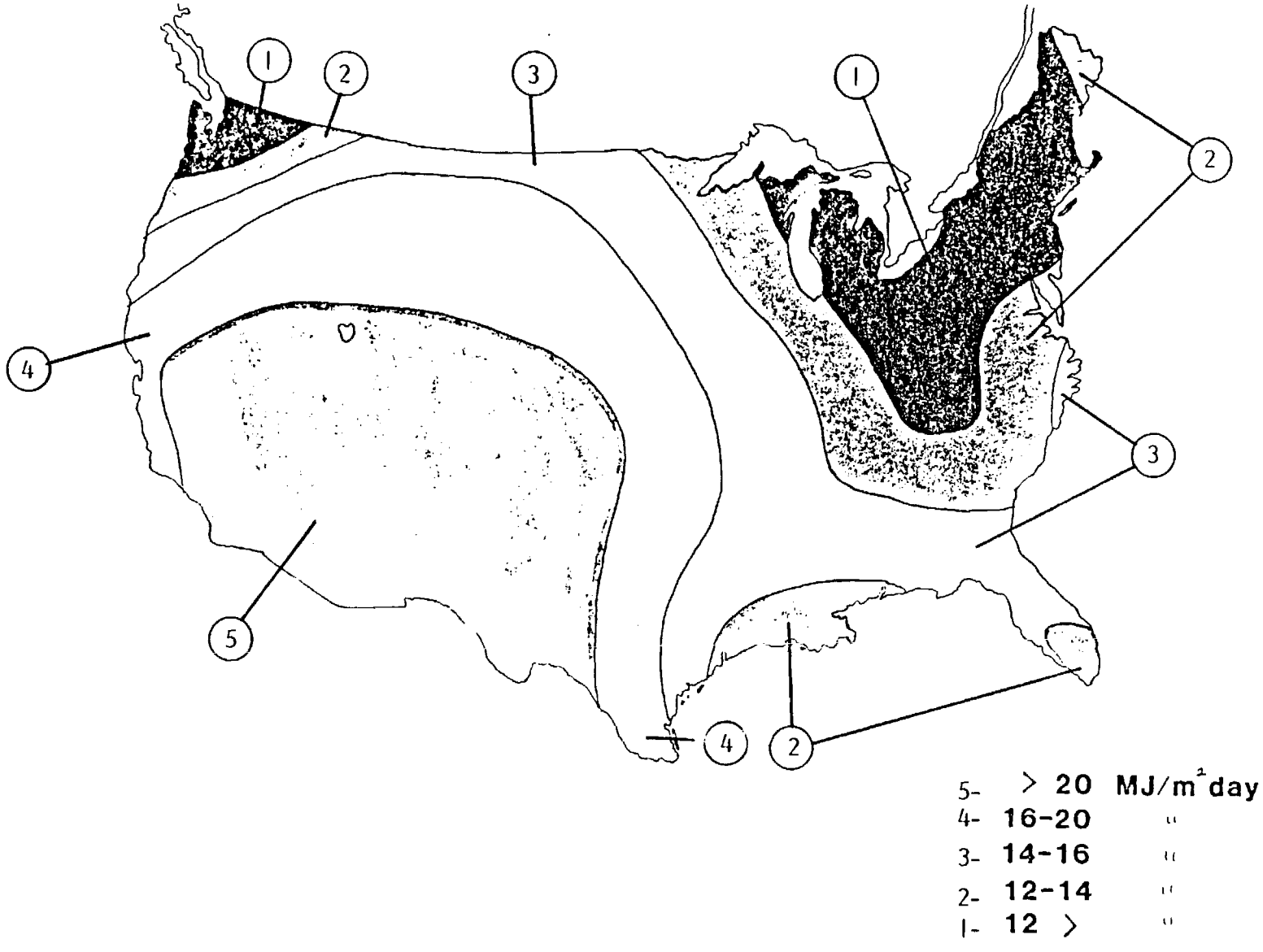

Figure IV-2. Direct Normal Solar Radiation.

electricity, conventionally generated electricity will be its major competitor. Electrical energy costs are available on a state by state bases, and can be expressed in 1976 dollars consistent with the data presented earlier in Table IV-3. Table IV-4 lists the mean electrical energy costs for each state. States that have high electrical energy costs include California, Connecticut, Hawaii, Massachusetts, New Hampshire, New Jersey, and Rhode Island. However, the electrical energy costs of many other states are not so low as to eliminate them from consideration.

By combining data, it is possible to define new composite criteria that simplify the decision process. Such a combination is the product of the total solar radiation on a horizontal surface and the cost of electricity. A high value for each of these parameters may indicate a potentially good location for PV application. However, by multiplying these factors together, the product will provide a composite criterion that may simply be ranked to identify the states that have the highest potential for flat plate PV arrays. The result of this multiplication process is listed in Table IV-4. The product of columns A and B will be highest for combinations that include high electrical energy cost and high insolation. As a result of this process the states that are indicated as having the greatest potential for PV power utilization are Hawaii, California, Arizona, and New Mexico. These states are the ones that are normally mentioned with respect to high potential for solar energy applications because of their excellent insolation. However, there are several states which do not have particularly good insolation that may represent a market because of the high electrical energy cost. These include: Delaware, Florida, Georgia, Massachusetts, Maryland, Missouri, Mississippi, Nebraska, New Hampshire, New Jersey, Rhode Island, and Utah.

Example of Market Identification

In order to illustrate the use of market factors to identify specific industries, the data presented in this chapter were used. The geographical market factors selected are electrical energy cost and PV energy production potential (insolation). The industrial market factor chosen is energy intensiveness. All data used in this example are presented in Tables IV-3 and IV-4.

Based on the energy intensiveness as measured by the electricity usage per value added, (Table IV-3), the two most energy intensive industry groups were selected. These energy groups are SIC3334 - Primary Aluminum and SIC2813 - Industrial Gases. These industry groups will be surveyed to identify specific plants in the geographic regions defined as areas of highest potential.

Table IV-4

INSOLATION AND ENERGY COST BY STATE

State	(A) Total Solar (Btu/Ft^2-Day) Insolation	(B) Electricity Cost in 1976 (Dollars/ Million Btu)	Product $/Ft^2-Day 10^{-6}
Alaska	751	7.81	5865
Alabama	1373	5.84	8018
Arkansas	1405	5.78	8121
Arizona	1855	6.99	12966
California	1620	8.31	13462
Colorado	1608	5.34	8587
Connecticut	1058	8.99	9511
District of Columbia	1208	N/A	-
Delaware	1208	8.19	9894
Florida	1462	7.04	10292
Georgia	1436	6.93	9951
Hawaii	1553	10.13	15732
Iowa	1304	6.43	8385
Idaho	1412	2.94	4151
Illinois	1247	6.95	8667
Indiana	1172	7.05	8263
Kansas	1494	5.06	7560
Kentucky	1218	5.26	6407
Louisiana	1402	4.29	6015
Massachusetts	1105	9.78	10807
Maryland	1229	7.79	9574
Maine	1085	5.37	5826
Michigan	1078	7.96	8581
Minnesota	1120	7.10	7952
Missouri	1339	6.88	9212
Mississippi	1389	6.73	9348
Montana	1143	1.75	2000
North Carolina	1341	6.15	8247
North Dakota	1210	7.12	8615
Nebraska	1399	7.12	9961
New Hampshire	1053	8.83	9298
New Jersey	1163	9.39	10921
New Mexico	1772	7.66	13574
Nevada	1755	5.90	10355
New York	1061	7.16	7597
Ohio	1117	5.81	6490
Oklahoma	1417	5.62	7964
Oregon	1239	2.52	3122
Pennsylvania	1120	7.49	8389

Table IV-4 (con't.)

INSOLATION AND ENERGY COST BY STATE

State	(A) Total Solar (Btu/Ft^2-Day) Insolation	(B) Electricity Cost in 1978 (Dollars/ Million Btu)	Product $\$/Ft^2$-Day 10^{-6}
Rhode Island	1112	9.99	11109
South Carolina	1357	5.57	7558
South Dakota	1314	6.17	8107
Tennessee	1289	5.69	7334
Texas	1543	5.70	8795
Utah	1695	5.82	9865
Virginia	1281	6.91	8852
Vermont	1021	6.82	6963
Washington	1123	1.11	1247
Wisconsin	1164	6.26	7287
West Virginia	1150	5.87	6751
Wyoming	1505	3.74	5629

Geographical areas of interest were identified through two market factors: PV energy production potential and electrical energy cost. From the data of Table IV-4, the states were ranked based on the total solar insolation and the top ten states were selected. Table IV-5 presents this list of the ten states with highest average insolation. Additionally, from Table IV-4, the states were ranked based on the cost of electrical energy, and the ten states with the highest cost of electrical energy were selected. This list is also presented in Table IV-5.

In order to define the states that represent good markets for photovoltaic systems, it is desirable to identify states that have both good solar insolation and high electrical energy costs. This was accomplished by taking states that appeared on both of the lists in Table IV-5. The only states that meet this criterion are Hawaii and California. So these are the states that are indicated as having the best potential for markets for photovoltaic systems.

For the purposes of this example, potential markets for photovoltaic systems are companies in Hawaii and California that are most energy intensive -- i.e. those either in the primary aluminum or industrial gas business. Identification of such companies may be accomplished in a number of ways, including manual searches of state industrial directories and automated searches of computerized data bases. For the purposes of this example, the EIS (Economic Information Systems, Inc.) computer data base was accessed, and an automated search was conducted. Companies with SIC codes 3334 or 2813 were identified in the states of Hawaii and California. As might be expected, with the cost of electricity so high in these states, there is not a large concentration of energy-intensive industries, and only three companies met all criteria. All three were located in California. The following is a list of the companies that were identified as potential markets for PV applications.

3334 PRIMARY ALUMINUM
TIMCO
2020 E. 220th St.
Long Beach, California 90810
County : Los Angeles
213-835-0115

Table IV-5

STATES WITH BEST INSOLATION
AND HIGHEST ENERGY COST

Rank	Insolation	Electricity Cost
1	Arizona	Hawaii
2	New Mexico	Rhode Island
3	Nevada	Massachusetts
4	Utah	New Jersey
5	California	Connecticut
6	Colorado	New Hampshire
7	Hawaii	California
8	Texas	Delaware
9	Wyoming	Michigan
10	Kansas	Alaska

3334 PRIMARY ALUMINUM
Halaco Engineering Co.
6200 Perkins Rd.
Oxnard, California 93030
County : Ventura
805-488-3684

2813 INDUSTRIAL GASES
NCG/Liquid Air Corp.
1588 Doolittle Dr.
San Leandro, California 94577
County : Alameda
415-635-9222

This example illustrates the methodology for using market factors to identify specific industries for PV systems. The methodology uses existing data and can result in the identification of potential markets by company name and address. Through selection of other market factors with less strict selection criteria, the number of companies that will be identified via this methodology can be controlled. In this way, the number of companies identified can be consistent with the scope of anticipated market development activities.

CHAPTER V

MARKETS FOR PHOTOVOLTAICS AS COMPONENTS IN MANUFACTURED GOODS

The identification of industries that may use photovoltaic generated electricity as a component of a manufactured product was addressed directly. From the PV market studies, a list of applications that are expected to be cost effective in the near term was extracted. The applications on that list were classified with the Standard Industrial Classification (SIC) number that described the industry that would manufacture that product. The four-digit SIC code can then be used with state industrial directories or computerized data bases to obtain names and address of specific manufacturers.

Manufacturers that use PV as components in their products may represent a significant market for photovoltaic cells and panels. In order to develop these markets, it is first necessary to identify products which contain PV power as integral parts of the systems. It is then possible to encourage the manufacturing of these products both as a market for PV cells and also as a consumer awareness tool. As small PV powered products gain more wide spread exposure, it will be easier to market larger systems.

The six major market identification and analysis studies are excellent sources of applications that may use PV power systems. These studies were used to develop a composite list of PV applications. The applications that were identified were organized and the four-digit SIC code of the manufacturer of the major system component was identified. The resulting composite list with SIC codes is presented in Table V-1.

Although there are a relatively large number of applications, many of the components associated with these applications are supplied by manufacturers with the same SIC code, therefore, the specific industry groups were identified and a listing of these groups was developed. Table V-2 lists the SIC codes and industry group description of the industry groups that were obtained from Table V-1. The list of industry groups in Table V-2 can be used as the first cut at identifying companies that may be a market for products that they manufacturer. There is no photovoltaic specific reasons to expect the manufacturers of devices that contain PV components to be located in any specific geographical area. Therefore, any manufacturer that makes products that are listed in Table V-1 are potential markets for PV components.

Table V-I

APPLICATIONS FOR PHOTOVOLTAIC POWER IN MANUFACTURED PRODUCTS

Transportation

3743 - Solar power for use in the caboose of a train.
3647 - Automobile headlight activated road markers.
3647 - Automobile automatic headlight adjustor (adjusts beam continuously rather than bright/dim).
3662 - Solar powered stop and go traffic signal.
3694 - Trickle charger for small aircraft
3612 - Solar powered lighting for highways and streets.

Application

3824 - Remote sensors used for traffic counting and control
3662 - Barrier flashers, warning lights for traffic control
3679 - Power supply for general aviation air craft rescue beacons
3679 - Power supply for general commercial aviation and military rescue beacons
3662 - Power for automatic railroad car identification system
3662 - Power for obstruction monitoring devices for railroad tracks.

Recreational

3631 - Solar powered outdoor barbecue grill.
3589 - Solar cell combination thermo-direct conversion swimming pool heating and filtration system.
3662 - Solar cell powered video camera and recorder system (portable).
3694 - Battery charging system for campers, motor homes.
3662 - Small solar arrays for minimal power at remote cabins and campsites.
3641 - Recharging system for nighttime illumination of ski areas

Security

3679 - Solar power used to detect failures in electrical and mechanical equipment.
3679 - Power supply for remote access controls and guard stations
3674 - Monitoring equipment to test water supplies against contaminants, poisons, etc.
3679 - Power supply for remote perimeter protection devices
3662 - Power supply for CCTV surveillance system
- Solar cell power for wireless intrusion sensors
3674 - Power for alarms that protect remote communication equipment - microwave relay stations, etc.

3674 - Medical/Veterinarian

3662 - Power supply for refrigeration of medical supplies in remote areas.
3829 - Temperature monitoring of livestock
3823 - Wildlife tracking transmitters powered by solar cells.

Marine

3647 - Power system for ocean data stations
3629 - Solar panels to maintain the charge on boat batteries

Table V-1 (continued)

3811 - Navigational aids: beacons, channel marker buoys
4811 - Emergency radio-telephone

Meterological

3679 - Power system for seismic detectors
3674 - Power system for rainfall and snow level recorders
3679 - Power system for total remote data acquisition systems.
3679 - Barometric pressure, air temperature, humidity sensors
3823 - Airport wind direction and speed sensor and transmitters
3679 - Solid state anemometer power supply
3823 - Ground-to-aircraft wind speed direction transmitter.

Environmental Protection

3823 - Water pollution sensors and telemetry equipment
3679 - Emission monitoring instruments for smokestacks
3679 - Sensors for the detection of air radioactivity
3679 - Power supplies for instrumentation used to monitor noise pollution
3679 - Air pollution sensors and telemetry equipment located in remote areas
3679 - Emission monitoring instruments for automobile.
3674 - Photovoltaic powered micrometerological monitoring systems at shole oil reclamation sites
3674 - Photovoltaic powered satellite data collection platforms (DCP) (for remote sites).

General Uses

3694 - Trickle charge for airplane battery
3573 - Charge calculators
3873 - Charge watch battery
3648 - Charge flashlight battery when light is not in use
3564 - Solar powered attic fans
3629 - Solar powered battery charger for backpack, used in emergency situation
3629 - Standard medium power module fixed installation
3679 - Standard medium power module - transportable
3679 - Standard low power module - fixed installation
3629 - Multipurpose low power module - portable (manpack)
3662 - Standard medium power module - sun tracking type
3629 - Standard low power module - portable - forestry communication system.

Communications

3679 - Power supply for unattended radio base station repeating installations
3679 - System power for isolated fire lookout towers
4899 - Lifeguard tower communications system
4811 - Land based emergency radio-telephones for motorist assistance
4811 - Fire reporting radio-telephones for wilderness areas
4811 - Mobile telephone company vans for temporary systems
4833 - Power for TV receivers in remote areas for reception of educational programs via satellite
4811 - Power for telephones in remote areas for reception of telephone transmissions via satellite

Table V-1 (continued)

Advertising

3629 - Power supply for battery recharging systems for outdoor billboards
3629 - Power supply for point of purchase temporary displays

Instrumentation Control

3823 - Command/control system for water supply distribution systems
3431 - Recycling of sanitary facilities in recreation areas
3679 - Desalination of water
3679 - Supply to power automated chemical mixing plants
3589 - Sewage processors and digestors
3561 - Power supply water pumps
3823 - Control systems for monitoring stream, lake and reservoir levels
3679 - Solar gravity motor and pump system

Agriculture

3523 - Supply for automatically dispensing insecticides
3561 - Combined solar and wind power system for electric water pumps in remote areas.

Education

3679 - Solar energy scientific experimentation kits for students.

Food Processing

3634 - Cooking devices utilizing both thermal and direct energy conversion.

Auxiliary Power

3679 - Power supply for oil drilling ocean platforms and barges

Refrigeration

3632 - Power supply for small refrigeration unit in remote or underdeveloped areas.
3585 - Solar powered mobile milk coolers
3585 - Solar powered refrigerated cars and trucks
3585 - Solar powered field chilling systems for harvested crops
3585 - Solar powered trout farming systems

Construction Industry

3679 - Power supply for portable power tools

Surveillance Systems

3662 - Solar powered approach sensors (for railroads and highways)
4811 - Solar powered iceberg tracking systems
4811 - Solar powered systems to monitor status of pipelines, oil and gas wells.
4811 - Solar powered fire detection systems.

Table V-2

SIC CODES AND INDUSTRY DESCRIPTION OF CANDIDATE INDUSTRY GROUPS

3523	Farm machinery and equipment
3561	Pumps and pumping equipment
3564	Blowers and fans
3573	Electronic computing equipment
3585	Refrigeration and heating equpment
3589	Service industry machiner, nec
3629	Electrical industrial apparatus, nec
3631	Household cooking equipment
3641	Electric lamps
3646	Commercial lighting fixtures
3647	Vehicular lighting equipment
3648	Lighting equipment, nec
3662	Radio and TV communication equipment
3674	Semiconductors and related devices
3679	Electronic components, nec
3694	Engine electrical equipment
3699	Electrical equipment & supplies, nec
3811	Engineering & scientific instruments
3823	Process control instruments
3824	Fluid meters and counting devices
3829	Measuring & controlling devices, nec
3861	Photographic equipment and supplies
3873	Watches, clocks, and watchcases.

The four-digit SIC code provides sufficient information to identify specific companies through the use of existing data bases. These data bases provide names, addresses and phone numbers of companies in each SIC group as well as other information such as volume of business that may be used to identify companies with the highest potential as markets for PV components. The most common manual data bases that can provide company names and addresses are the state industrial directories. There are also a number of computerized data bases that are suitable, such as those maintained by Dunn and Bradstreet and Economic Information Systems, Inc.

Specific companies can be identified using the industrial data bases and the four-digit SIC industry group. An application or related group of applications may be selected from Table V-1. For example, there are ten specific applications listed in Table V-1 that contain major components manufactured by SIC group 3662 (Radio and TV communications equipment). Therefore, this group may be selected for more detailed investigation. The automated data bases would be searched to provide a list of all companies with an SIC number of 3662. Based on this list, questionaires may be mailed to these companies to determine the specific type of products manufactured at those plants, and appropriate follow-up can be conducted.

CHAPTER VI
SUMMARY

The work that is documented in this report was designed to facilitate the process of matching photovoltaic suppliers with potential industrial users. There are several specific products. First is a directory of PV manufacturers, distributors, and consultants. Second is an annotated bibliography of photovoltaic market studies. Third, factors are defined that can be used to identify specific potential industrial PV users. Fourth is a methodology for identifying specific companies that will represent the mosts probable markets for early use of industrial photovoltaic power.

The directory of PV manufacturers, distributors, and consultants reports the names and addresses as well as the major products and services of PV firms. Included in the directory are 139 companies or organizations which are currently active in the photovoltaic market place. This represents a doubling of the participants in the market place in the last two years. There are 27 companies that manufacture photovoltaic cells, 25 that manufacturer flat plate PV modules and 16 that manufacturer concentrating PV modules. There are also 38 companies that distribute flat plate PV modules and 13 that distribute concentrating PV modules. There are many more firms that can provide remaining system components such as voltage regulators, battery storage, and inverters. Almost all of these companies have entered the PV market in anticipation of near term markets for stand alone, isolated, and special purpose systems.

An annotated bibliography of PV market studies was developed. Market studies were identified through a combined manual and computer based literature search. The reports of the market studies were obtained and a bibliography was developed that included an abstract and near term market conclusions as well as bibliographic information.

There have been six comprehensive studies to identify and analyze the role of terrestrial photovoltaic systems. The first of these studies was performed before the oil embargo. The remaining five studies were performed to define the type and level of federal support for the development of photovoltaic technology. All of these studies dealt primarily with near-term markets. They identify small and/or isolated applications that are likely to be cost effective in the near term. Applications for larger PV systems such as industrial and utility systems are

expected to be cost effective when the costs of photovoltaic components and energy storage systems are further reduced.

The remaining 38 studies abstracted in the bibliography were directed toward specific aspects of terrestrial PV applications. Some of these studies concentrated on the estimation of the market size and the identification of specific PV products such as highway applications, communications, cathodic protection, and water pumping. Some of the other studies addressed the design and economic analysis of specific applications such as forming batteries. However, these 38 studies did not attempt to address the comprehensive nature of the future markets for PV systems.

Data and expertise from several sources were used to identify factors that can be used as criteria to select industries as potential markets for photovoltaic energy systems. The principal sources were the Industrial Applications and Policy Branch of SERI, published literature, and personal expertise of the Georgia Tech Research staff. The resulting list of market factors was categorized; and data sources were identified for geographical and industrial categories, forming a basis for the identification of specific PV markets.

Methodology was developed and demonstrated on a limited example that uses the market factors to identify specific industrial plants for photovoltaic power systems. The basic methodology was to screen industry categories by successive applications of market factors, progressing from general to more specific data. The result is a small number of industry categories (based on four-digit Standard Industrial Classification and geographical location) which represent the most probable markets for photovoltaic systems as sources of industrial power. Although the order in which the market factors are used has only minimal impact on the final results, it may have a significant impact on the amount of work required to arrive at the final results. Therefore, a specific sequence for using the market factors was recommended.

A limited amount of data relevant to the market factors were collected and analyzed. Based on energy intensiveness, the primary metal industries (SIC33) rank the highest, but there are several industry groups at the four-digit level that are quite energy-intensive. When the PV energy production potential is evaluated, the southwestern states have the highest potential, and the northeast is among the least likely areas. However, when the cost of electrical energy is considered, several of the northeastern states are indicated as having significant potential because the cost of electrical energy is so high.

The methodology to identify specific potential markets was exercised on a limited scale. The results were selection of two highly energy intensive SIC groups: SIC 3334 - Primary Aluminum and SIC 2813 - Industrial Gases. The two most likely states based on insolation and electrical energy costs are Hawaii and California. There are no industries in these SIC groups in Hawaii and only three in California. This technique of identifying potential markets is relatively simple to perform and results in specific company names and addresses.

Markets are also anticipated for PV as components in complete systems that will be marketed by various manufacturers. Market studies were used to identify applications for PV power that will be cost effective in the near term. Four-digit SIC categories were identified for the manufacturers of these systems, and a composite list of manufacturer categories was developed. This list of 23 four-digit SIC's can be used to identify companies which are potential markets for photovoltaic components.

Appendix A
CONFERENCE

Appendix A

PHOTOVOLTAIC ENERGY SYSTEMS FOR INDUSTRIAL ENERGY APPLICATIONS RESULTS OF CONFERENCE SESSION--9 JANUARY 1981

Purpose: Identify characteristics of industries that can be powered by photovoltaic energy systems.

Format: We concentrated on the PV-industrial characteristics first as individuals and second as a group. A response sheet was used to record initial responses in each catagory. It was not intended that individuals should research any of the answers, but rahter draw responses from experience. Participants were instructed to feel free to include comments that were not within the listed catagories since the questions are intended to stimulate ideas and minimize the time commitment of each individual.

Block I - Initial Response

QUESTION:

Based on your present knowledge of photovoltaics and photovoltaic energy systems, what do you think are the three most important technical criteria that an industry must have to be able to use photovoltaic energy?

RESPONSES:

1. Use DC Power
2. Be in an area of high insolation
3. The Thermal-to-electric load ratio should be compatable with type of collector used, or primarily electric load.
4. Work cycle consistant with solar cycle, i.e. daylight operation.
5. Be located in clean area
6. Be in area with high utility rates
7. Be willing to consider PV as well as other alternatives such as cogeneration.
8. An inovative attitude on the part of the managers.
9. Industry should be able to tolerate both periodic and random losses of power.

NOTES:

Photovoltaic energy conversion systems convert solar radiant energy directly into electrical energy. The physics and the manufacturing technology are sophisticated, but knowledge of them is not necessary as part of the planning process. From a planning point of view, the PV array can be treated as a "black box" with specified performance characteristics such as:

Type of Power	- D.C. electric
Voltage	- Specifiable constant
Current	- Peak specifiable operating variable
Efficiency	- 6% - 15% depends on specific type of array
Reliability	- Technical - 99% - Operational - depends on weather and location

Availability - Night - 0
- Day - depends on weather

The output character of the basic PV system can be modified by addition of additional functional components:

Inverter - Converts D.C. to A.C. Power
Energy Storage - Levelizes the availability of power

Although it is a slight over simplification, the technical problems are solvable and only require capital. As a practical matter, the cost is usually the decision criterion for most business decisions, and therefore, PV systems are not considered as cost competitive. The cost of PV systems has been reduced by an order of magnitude during the past five years, and the goal is another order of magnitude reduction in cost during the next five years.

For our present purposes, we do not want to get burdened with too many specifics and technical details, because these factors may change as a result of technological advances. Also we would like to consider the energy/use system. It is important to keep in mind that the introduction of any new technology or energy source has had obstacles to overcome. The technologies associated with the modern electric utility have been developed over the past 70 or 80 years and are not the result of some technological break-through that allowed the overnight electrification of the United States.

Block 2 - Insolation/Meteorological

QUESTION:

What are the characteristics of an industry that might use photovoltaic energy, with respect to insolation and meteorological conditions?

RESPONSES:

1. High insolation
2. Arid
3. Industry has high summer load such as food refrigeration
4. Located in areas that will not require excessive protection from conditions such as wind, storms, sand storms, hail, and snow.
5. Ambient temperature should be low to improve efficiency

NOTE: Insolation depends primarily on solar geometry and meteorological conditions. The maximum amount of solar power that reaches the earth's surface is appriximately 1.0 kW/m^2. The actual amount of energy received at a given point varies with the cycle of night and day, the amount of cloud cover, the atmospheric turbidity, the change of seasons, and the amount of air pollution. At 43^o north latitude this makes a difference of 6 hours of sunshine during the day that depends on the season of the year.

In Southern California the average amount of solar energy received is 9.4 kWh/m^2 per day while in Barrow Alaska, the average received energy is only 3.4 kWh/m^2 per day. This difference alone will cause a significant difference in the economics of using photovoltaics energy systems. However, superimposed on these average values are the seasonal variations.

Block 3 - Location:

QUESTION:

What criteria relevant to location would an industry have that would use a photovoltaic energy system.

RESPONSES:

A. From a national point of view. (Policy related)
   1. Available land and low land cost
   2. Energy costs high
   3. Environmental restrictions and policy favorable to PV

B. From a local point of view. (Business related)
   1. Low land cost
   2. Remote site (plenty of space for collectors, and away from dust and pollution producing industries)

NOTE: Superimposed on the characteristics of an industry are the general planning considerations such as proximity of raw materials, location of market, availability and quality of labor force, and quality of living conditions.

Block 4 - Economic

QUESTION:

What economic criteria would be relevant to an industry that would use photovoltaic energy?

RESPONSES:

1. High energy costs (both thermal and electrical)
2. Long payback periods acceptable (this implies a large company)
3. Area where expensive environmental controllers are required for conventional energy sources.
4. Available capital or credit for investment.

NOTE: Almost all of the factors used as decision criteria are expressed in economic or financial terms. e.g. capital cost, cost of capital, fuel cost, busbar, energy costs, etc.

Block 5 - Institutional

QUESTION:

What institutional criteria will influence the use of photovoltaic energy by industries?

RESPONSES:

1. Utilities and regulatory agencies supportive and not obstructions
2. Tax structure supports alternative energy.
3. Strict Environmental controls and sun rights.

4. Corporate and management attitudes.
5. Public opinion supports alternate energy.

NOTE: It may occur that the technical problems are solvable but regulations, policies, taxes, etc. will make the photovoltaic system too expensive.

Block 6 - Competing Energy Sources

QUESTION:

What types of competing energy sources will encourage or discourage the use of photovoltaic energy?

RESPONSES:

A. Encourage:
1. Oil
2. Solar thermal (alternative in general)
3. Hydroelectric

NOTE: In general, situations that generate interest in alternative energy sources, such as in-plant generation or cogeneration, will also be favorable to photovoltaics.

RESPONSES:

B. Discourage:
1. Nuclear
2. Coal

These types of plants are low fuel cost, base loaded plants that are operated at full or near full capacity whenever possible. Advances in nuclear technology and reduction of safety and environmental regulations would make it very difficult for photovoltaics to compete with nuclear plants.

NOTE: There is a general trend toward increasing energy costs that are related directly to the cost of oil. However, in the United States, coal and nuclear energy will significantly reduce the dependance on oil for electrical generation.

Block 7 - Follow-up

QUESTION:

List any other criteria that are important to the development of industrial applications of photovoltaic energy?

RESPONSES:

1. People's attitudes are very important (corporate management as well as the people in the community of the photovoltaic powered industry.)
2. The industry will probably have the following characteristics:
   a. high technology industry (willing to accept and try new approaches)
   b. Sophisticated users (highly trained engineering an technological understanding.)
   c. Small-scale (large scale plants will locate near low cost energy source such as nuclear power plant or hydroelectric plant.)

NOTE: In the mature market the combination of all factors will be used as the basis for the decision to invest in photovolatic power systems. This may make it more difficult for photovoltaics to compete directly on the basis of energy cost but the economic parameters will be much more stable. Corporations will make decisions based on existing decision criteria and will make trade-offs between fuel cost and capital cost or energy storage and work schedule.

Appendix B
SOURCES OF MARKET FACTOR DATA

Appendix B
SOURCES OF MARKET FACTOR DATA

Data sources for categories that will aid in the identification of industries that will be the first to have cost effective applications for photovoltaic power as the cost of energy increases and the cost of photovoltaics decreases. Table I lists the data categories that have been identified as pertinant to the industry identification. On the following pages the data sources for each category are described. This will be done at two levels of detail. First the data sources will be identified and second some of the specific reports and articles that are relevant to the data category and identified.

Markets by Four-Digit SIC

A1. Use of D. C. power

DATA SOURCES

Trade Associations

Electrical Equipment Representatives Association(EERA)
P.O. Box 3417
San Diego, CA 92103
(714) 299-9386

Independent Battery Manufacturers Association (IBMA)
100 Larchwood Dr.
Largo, FL 33540
(813) 586-1409

National Association of Electrical Distributors (NAED)
600 Summer St.
Stamford, CT 06901
(203) 327-1290

National Electric Sign Association (NESA)
2625 Butterfield Rd.
Oak Brook, IL 60521
(312) 323-3600

National Electrical Manufacturers Association (NEMA)
2101 L Street N. W.
Washington, DC 20037
(202) 457-8400

Small Motor Manufacturers Association (SMMA)
435 N. Michigan Ave., 17th Floor
Chicago, IL 60611
(312) 644-0828

Electronic Industries Association (EIA)
2001 Eye St. N.W.
Washington, DC 20006
(202) 457-4900

SPECIFIC DATA SOURCES

A study has just been completed (to be publiched by April 1981)
Sponsor: SANDIA Laboratories
Contract #: 13-0278
Contractor: General Electric Company, Space Division
Project Director: Edward Mihalick (215) 962-5842
Title: Identification of Electrical Loads which can Utilize Direct Current Electricity
Note: I talked with the Project Director. He said there is a thorough bibliography that identifies industrial applications for D. C. power. He is sending me a copy of the bibliography and will send a copy of the report as soon as SANDIA approves the final report. They considered most industries as good candidates if PV could supply 5 percent of the load.

A2. Energy consumption compatible with availability of solar radiation (i.e., both diurnal and annual).

Solar Radiation Patterns

DATA SOURCES

National Climatic Center, Ashville, NC

Sandia Laboratories, ABQ, NM

Battelle Northwest Laboratories, Richland, WA

Solar Energy Information Data Bank
Solar Energy Research Institute (SERI)
1617 Cole Boulevard
Golden, CO 80401
(303) 231-1032

SPECIFIC DATA SOURCES

Cinquemani, V., J. R. Owenby, Jr., and R. G. Baldwin, Input Data for Solar Systems, U. S. Department of Energy, Interagency Agreement No: E(49-26)-1041, Nov. 1978.

SOLMET, VOL I - User's Manual, TD-0824, Hourly Solar Radiation-Surface Meteorological Observations. National Climatic Center, Ashville, North Carolina.

Boes, E. C., et. al., "Availability of Direct, Total, and Diffuse Solar Radiation to Fixed and Tracking Collectors in the USA," Sandia Laboratories, Albuquerque, New Mexico, SAND 77-0885, August 1977.

Energy Consumption Patterns - by SIC code

SPECIFIC DATA SOURCES

ENERGY USE ANALYSIS OFFICE, Office of Applied Analysis, Energy Information Administration, DOE (202) 633-8510.

OFFICE OF ECONOMIC ANALYSIS, Office of Applied Analysis, Energy Information Administration, DOE, (202) 633-8720

ECONOMIC FIELDS, Bureau of the Census, Department of Commerce, Elmer S. Biles, Senior Economic Advisor, Energy Statistics Coordinator, Federal Center, Suitland, MD 20233, (301) 763-7184.

CONSUMPTION DATA SYSTEM, Program Development, Energy Information Administration, DOE, (202) 634-5641.

ELECTRIC POWER RESEARCH INSTITUTE, Palo Alto, CA 94303

Whisnant, R. A., C. B. Morrison, N. G. Staffa, R. D. Alberts, Application Analysis and photovoltaic System Conceptual Design for Service/Commercial/Institutional and Industrial Sectors, Research Triangle Institute, Sandia Laboratories Contract No. 07-6936, SAND79-7020, December 1979.

Note: This is a particularly RELAVENT study.

It addresses many of the significant market factors based on the two-digit

SIC. It also gives a lot of good references.

"Photovoltaic Systems Concept Study, Final Repoty." Sylmar, California: Spectrolab, Incorporated, April 1977.

" Conceptual Design and Systems Analysis of Photovoltaic Power Systems," Final Report, ERDA Contract No. (11-1)-2744, Westinghouse Electric Corporation, 1977.

" Conceptual Design and Systems Analysis of Photovoltaic Systems. Final Report." Pittsburgh, Pennsylvania: Westinghouse Electric Company, 1977.

" Conceptual Design and Systems Analysis of Photovoltaic Systems. Final Report." Philadelphia, Pensylvania: General Electric Company, March 1977.

A3. Energy intensive (e.g., a large ratio of energy costs to value added)

DATA SOURCES

Energy Use Analysis Office
Office of Applied Analysis
Energy Information Administration
(202) 633-8510

Office of Economic Analysis
Office of Applied Analysis Energy Information Administration, DOE
(202) 633-8720

Economic Fields
Bureau of the Census
Department of Commerce
(301) 763-7184

Consumption Data System
Program Development
Energy Information Administration, DOE
(202) 634-5641

Electric Power Research Institute
Palo Alto, CA 94303

SPECIFIC DATA SOURCES

Kutscher, Ronald E., "The Influence of Energy on Industry Output and Employment," Monthly Labor review, Dec. 1979.

(Note: this is a KEY source of information, sone of the data is presented by 2-digit SIC and some by 4-digit SIC.

A4. Large electrical load

DATA SOURCES

U.S. Department of Commerce, Bureau of the Census

U.S. Department of Energy, Energy Information Administration, Consumption Data System, (202) 634-5641

SPECIFIC DATA SOURCES

Annual Survey of Manufacturers 1974, Fuels and Electric Energy Consumed, U. S. Department of Commerce, Bureau of the Census, M74(AS)-4.2.

Statistical Abstract of the United States, U. S. Department of Commerce, Bureau of the Census.

National Energy Accounts: Energy Flows in the U. S. 1947-1972, Vol. I, Jack Faucett Associates, Inc., Fedral Energy Administration, July 1975. (Note: has some information by 4-digit SIC)

Current Industrial Reports, US Department of Commerce, Bureau of the Census. (Note: This series contains data on approximately 4000 products that represent 34% of all manufacturing in the US. This is a KEY information source.

A5. Currently generating electricity for own use

DATA SOURCES

WASTE ENERGY UTILIZATION AND COGENERATION BRANCH
CONSERVATION Research and Development Division
Industrial Programs
Conservation and Solar Energy, DOE
John Eustis, Chief, CS-40
FORSTL, MS 2H085
Washington, DC
(202) 252-2084

Commercialization - Resource Manager
COGENERATION
Conservation and Solar Energy
20MASS, Room 3108, MS 2221C
Washington, DC
(202) 3676-4907

A6. Often are remotely sited from the utility grid

DATA SOURCES

National Rural Electric Cooperative Association (NRECA)
1800 Massachusetts Ave., N.W.
Washington, DC 20009
(202) 265-7400

A7. Located in geographically favorable areas (see B)

N/A

Geographical Markets

B1. Output of different types of PV arrays (e.g., concentrating vs. non-concentrating)

DATA SOURCES

SPECIFIC DATA SOURCES

W. D. Merrill, R. J. Blaha, and R. L. Pickrell Dynamic Analysis of a Photovoltaic Power System with Battery Storage Capability. Jul. '79, 47p. NASA-TM-79209, E094 Contract DE-AI01-79ET20485

T. J. Lomberski, A.F. Malberg, K.E. Melick, r.M. Turfler, and M.G. Semmens. Photovoltaic Transient Analysis Program: User's Guide Volume IV. Supporting Data. Oct. '78, 155p., Contract EY-76-C-04-0789.

V.E. Dudley, and R.M. Workhoven. Summary Report" Concentrating Solar Collector Test Results, Collector Module Test Facility. May '78, 52p. Contract EY-76-C-04-0789.

J.H. Yee. Systematic Computation of the Performance of Photovoltaic Cells Based

on First Principles: First Report. Jan. '79, 38p. Contract W-7405-ENG-48

L. H. Goldstein, and G. R. Case. PVSS. A Photovoltaic System Simulation Program Users Manual. Jun. '77, 46p. Contract EY-76-C-04-0789

E. L. Burgess. Photovoltaic Energy Conversion Using Concentrated Sunlight. 1976, 7p. CONF-760832-5. Contract E(29-1)-789.

B2. Utility service areas where industrial electricity rates are high

DATA SOURCES

ELECTRIC ENERGY SYSTEMS DIVISION
Resource Applications, DOE
(202) 633-9296

ELECTRIC POWER RESEARCH INSTITUTE
Palo Alto, CA 94303

SPECIFIC DATA SOURCES

Electric Rate Book, 1974, Edison Electric Institute, New York, New York.

"The Cost of Energy From Utility-Owned Solar Electric Systems," ERDA/JPL-1012-76/3, 1976.
(Note: this sutdy provides the methodology for comparing the cost of energy.)

Energy Data Report, Typical Electric Bills-January 1, 1979, US DoE, Energy Information Administration, DOE/EIA-0040(79), October 1979.

B3. States with substantial financial incentives for PV systems in industry.

The incentives vary considerably from state to state, and photovoltaic incentives are not specifically addressed. There are several good sources of information:

DATA SOURCES:

RESEARCH AND ANALYSIS DIVISION
Office of the Assistant to the
Secretary for Legislative Affairs, DOE

FORSTE, MS 8G031
(202) 252-8687

OFFICE OF LEGISLATION
Office of the General Counsel
Federal Energy Regulatory Commission, DOE

NEW LEGISLATION AND PROGRAM BRANCH
Conservation Technology Deploymentand Monitoring Division
Industrial Program Conservation and Solar Energy, DOE
(202) 252-2384

SPECIFIC DATA SOURCES:

Solar Legislation
National Solar Heating and Cooling Information Center
Department of Hosuing and Urban Development, DOE
Rockville, MD 20850

This organization has published a report on Solar Legislation that compiled the solar related legislation at the federal and state level on a state by state basis.

"Solar Tax Credit", Solar Engineering, July, 1980

Warren, Michae, Problems in the Administration of State Solar Legislation, SERYTR-62-266, July, 1969.

B4. High industrial growth regions

DATA SOURCES

Department of Commerce
Bureau of the Census
Industry and Trade Administration

SPECIFIC DATA SOURCES

1980 US Industrial Outlook for 200 Industries with Projections for 1984, US Department of Commerce, Industry and Trade Administration, GPO # 003-008-00181-5, January 1980.

B5. Markets by Four-Digit SIC (through Paper Studies) Areas with stringent air quality regulations and restrictions

DATA SOURCES

NEPA AFFAIRS DIVISION

Environmental Compliance and Overview
Environment, DOE

Robert J. Stern, Acting Director, EV-11
FORSTL, MS 4G064
(202) 252-4600

OFFICE OF ENVIRONMENTAL REVIEW
Environmental Protection Agency

Cathy Wilson
401 M Street, S.W., MS !104
Washington, D.C. 20460
(202) 245-3006

OFFICE OF TECHNOLOGY IMPACT
Environment, DOE

Peter W. House, Director, EV-20
FORSTL, MS 4G085
(202) 252-2061

OFFICE OF HEALTH AND ENVIRONMENTAL RESEARCH
Environment, DOE

William W. Burr, Jr., Acting Director, EV-30
GRN, MS E201
(301) 353-3153
FTS 233-3153

B6. Markets by Four-Digit SIC (through Paper Studies) Areas where utilities and regulatory agencies are supportive of PV systems

DATA SOURCES

ELECTRIC POWER RESEARCH INSTITUTE
Palo Alto, CA 94303

PUBLIC INQUIRIES BRANCH
Public Information Division
Office of Congressional and Public Affairs
Federal Energy Regulatory Commission, DOE

SPECIFIC DATA SOURCES

Laitos, Jan, and Randall J. Feuerstein, Regulated Utilities and Solar Energy, Solar Energy Research Institute, DOE, SERI/TR-62-225, June, 1979.

Appendix C
GLOSSARY OF TERMS

GLOSSARY

ENERGY STORAGE - a bank of batteries or other mechanisms which store energy that is generated by photovoltaic array, or through inherent self-storing characteristics of the PV system. Examples of systems not requiring a battery for storage are water pumping and refrigeration systems where the water and "cold" are stored. The firms listed in this report under the catagory of Energy Storage deal with chemical storage batteries.

INVERTER - a device that changes the direct current produced by the cells or stored in batteries to alternating current for use with alternating current appliances and motors.

LOAD CONTROLLER - a device that protects the battery systems from both excessive charge and discharge.

PHOTOVOLTAIC CELLS - disks or squares of specially treated silicon or other material which, when exposed to light, generate a voltage.

PHOTOVOLTAIC MODULES - a specific grouping of photovoltaic cells which are encapsulated or sealed between metal and transparent plates. Flat plat modules - designed so that there is no focusing of sunlight on the cells. Concentrating (focusing) modules-designed to concentrate sunshine on the cells.

PHOTOVOLTAIC PANEL - another term for a flat-plate photovoltaic module.

VOLTAGE REGULATOR - a device to insure that the voltage from the photovoltaic arrays and battery systems remains within a predetermined range.